(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 513 527 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent: **05.12.2001 Bulletin 2001/49**

(51) Int Cl.[7]: **H04L 5/14**, H04L 27/00, H04B 3/20, H04J 3/16

(21) Application number: **92106134.7**

(22) Date of filing: **09.04.1992**

(54) **High speed two wire modem**

Zweidrahtmodem für hohe Geschwindigkeit

Modem à deux fils pour grande vitesse

(84) Designated Contracting States:
BE DE FR GB

(30) Priority: **15.04.1991 US 685571**

(43) Date of publication of application:
19.11.1992 Bulletin 1992/47

(73) Proprietor: **MOTOROLA, INC.**
Schaumburg, IL 60196 (US)

(72) Inventors:
- **Sridhar, Manickam R.**
Norton, Massachusetts 02766 (US)
- **Mukherjee, Aniruddha**
Framingham, Massachusetts 01701 (US)
- **Moran III, John L.**
Millville, Massachusetts 01529 (US)

(74) Representative: **Dunlop, Hugh Christopher et al**
Motorola,
European Intellectual Property Operations
Midpoint
Alencon Link
Basingstoke, Hampshire RG21 7PL (GB)

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Printed by Jouve, 75001 PARIS (FR)

Description

Background of the Invention

[0001] The present invention relates to modems, in general, and more particularly to a modem for selecting a carrier frequency and a baud rate from a predetermined plurality of carrier frequencies and baud rates to communicate with another modem over a communication media of a data communications network in a full duplex mode the selection being based on estimated characteristics of the communication media, and a method of operating a modem by combining the processes of estimating channel characteristics and estimating range in a common startup procedure characterized by a plurality of successive time segments.

[0002] In a data communication network, digital data among other data, may be communicated at a data bit rate from one modem to another modem through a communication media, which may be a leased line of the network or a dial up connection of a general switched telephone network (GSTN), for example. Generally, modems operate at a fixed carrier frequency and a fixed modulation or baud rate and attempt to optimize the data exchange bit rate based on the conditions of the communication media over which they are communicating. In order to accomplish an optimum data bit rate, contemporary modems utilize a startup learning procedure before commencing communication during which the modems perform certain predefined start up procedures which may include a line probing sequence, for example, to establish the media characteristics over which communication will take place. The current state of the art CCITT standard for two wire full duplex modems is V.32 and V.32bis. An example of a modem employing the V.32 standard today includes the Codex Model 2264 (TM). An example of a state of the art modem using line probing is the Codex Modem Model 3680 (TM).

[0003] In addition, two wire modems for operating in a full duplex mode generally employ an echo canceller to cancel from the received signal any near end and far end echoes resulting from its concurrent signal transmissions. These modems include a ranging sequence as part of the startup procedure to determine the round trip signal delay time over the media to and from a remote modem which is used by the echo canceller thereof. The ranging task is performed separate and distinct from any line probing tasks. Further, in two wire, full duplex transmission systems, there are system nonlinearities which affect not only the signal transmission, but also both of the near end and far end echoes resulting therefrom. Conventional line probing training sequences do not measure the nonlinearities of the echo signals and, for this reason, cannot provide adequate estimates for echo cancellation purposes.

[0004] Still further, if during data communication between two modems, a malfunction, like loss of synchronization, is detected, the modems presently on the market resort to breaking communications and repeating the entire startup procedure, including both line probing and ranging tasks, which is a very lengthy and cumbersome retraining process. Moreover, only one of the communicating modems is generally designated to initiate this retraining process upon malfunction which adds further complications.

[0005] US-A-5048054 discloses a two-wire modem in accordance with the preamble of the independent claim 1.

[0006] The present invention offers aspects intended to alleviate the aforementioned drawbacks of the current modems. These aspects will be better understood from a description of the preferred embodiment found hereinbelow taken together with the accompanying drawings.

Summary of the Invention

[0007] In accordance with the present invention, a two wire modem in accordance with independent claim 1 is provided.

[0008] In accordance with a second aspect of the invention, there is provided a method as setforth in claim 7.

Brief Description of the Drawings

[0009] Fig's. 1 and 2 are block diagram illustrations of an exemplary data communications network model suitable to describe the background environment of the present invention.

[0010] Fig. 3 depicts a functionally block diagram schematic of a two wire modem capable of operating in a full duplex mode and suitable for embodying the principles of the present invention.

[0011] Fig. 4 is a functional block diagram schematic of a series of modules suitable for embodying an FFT processor for performing the estimation of signal or echo characteristics of the communication media for use in the embodiment of Fig. 3.

[0012] Fig's. 5 - 12 depict "hand-shaking" signal exchange between a modem pair for start up training and the initiation of retraining during data transmission in accordance with the principles of the present invention.

[0013] Fig's. 13A - 13D represents suitable software programming for embodying the functional modules of the modem of Fig. 3 operating in a call mode.

[0014] Fig's. 14A - 14D depict suitable software programming for embodying the functionally modules of the modem of Fig. 3 operating in an answer mode.

[0015] Fig. 15 depicts a method flowchart of a suitable embodiment of another aspect of the present invention.

Description of the Preferred Embodiment

[0016] Fig's. 1 and 2 are block diagram illustrations of an exemplary data communications network model in

which two modems denoted as A and B, of the two wire variety are communicating through a general switched telephone network (GSTN). In the present example, the modems A and B are coupled to the GSTN over two wire line connections to hybrids H(A) and H(B), respectively, which convert the two wire connections to four wire connections of the GSTN. Loop losses of the two wire connections, coupling modems A and B to the GSTN, are represented by the blocks L(A) and L(B), respectively, and the reflected respective impedances are represented by $Z_L(A)$ and $Z_L(B)$. The trunk losses of the network are lumped according to direction of signal communication and are represented by the directional triangles TR.

[0017] The illustration of Fig. 1 is used to depict a near-end echo signal 10 resulting from the transmitted signal 12 from modem B and reflected from the hybrid H(B). The illustration of Fig. 2 depicts a composite signal 14 comprising at least two far end echo signals 16 and 18 resulting from the transmitted signal 12 from modem B. The far end echo signal 16 is a residual signal remaining as a result of a non-ideal hybrid match situation, which is commonly referred to as "trans-hybrid loss" and is dominant in most far-end echo signals. The other echo signal 18 is a residual signal remaining as a result of the transmission signal 12 traversing the local loop L (A), being reflected off the remote modem A due to a non-ideal impedance termination in a modem and traversing back along the same local loop L(A) and then combining with the echo signal 16. The echo signal 18 is generally smaller than the echo signal 16 since it goes through the loop L(A) twice and the minimum return loss (reflected signal) for a modem is on the order of 11db in order to meet certain standards.

[0018] In operation, modem B in communicating with modem A transmits its signal 12 traversing the local loop L(B), the hybrid H(B) the trunk loss TR, the hybrid H(A) and the loop L(A), which in combination constitute the communication media between modems A and B. Concurrently therewith, modem B receives in a full duplex mode not only the transmitted signal from modem A but, in addition, the near end echo signal 10 and composite far end echo signal 14. The communication frequency spectrum of the communication media is referred to herein as the channel and the round trip delay over the channel between the call and answer modems is referred to herein as the range. Accordingly, in order to provide a viable estimate of the channel characteristics for optimizing data bit rate and echo cancellation, the near and far end echo signals including echo nonlinearities should be learned and taken into consideration as part of the training sequences at the modems A and B.

[0019] For the present embodiment, modems A and B may be implemented much the same or similar to the aforementioned modems marketed by Codex Corporation bearing Model 2264 which have been marketed more than 1 year prior to the filing date of the instant application and are described in the publication "2264 Modem Users Manual", 08789, Rev. B, published code LP, published July, 1989 by Codex Corporation.. This manual or manuals are being incorporated by reference herein to provide more specific details of the structure and operation of a suitable modem used in connection of this preferred embodiment.

[0020] Fig. 3 depicts a functional block diagram schematic of a two wire modem capable of operating in a full duplex mode and suitable for embodying the various aspects of the present invention. As in the Codex model 2264, the function of the blocks of the embodiment of Fig. 3 may be implemented in software programs of at least one signal processor similar to the type manufactured for Codex Corporation bearing Model No. 60423-51, for example. The modem processor(s) will not be described in detail herein as the use of a signal processor(s) in the control and implementation of modem functions is considered well-known.

[0021] Referring to Fig. 3, at the heart of the exemplary modem is a functional controller module 20 which functions to provide information to the various other functional modules of the modem in accordance with a predetermined timing sequence which will be described in greater detail hereinbelow. The present modem is intended to operate with quadrature amplitude modulation (QAM) for each channel with synchronous line transmission at a selected one of the following plurality of modulation or baud rates: 2400, 2743, 2954, and 3200 as will be more fully understood from the description herebelow. The present modem is also designed to operate at the following data rates: 9600, 12000, 14400, 16800, 19200, 21600, 24000, and 25600 bits per second. In the present embodiment, the above rates may use a Codex Proprietary Precoding Modulation Scheme, combined with 4D trellis coding. Still further, a plurality of carrier frequencies which may be used by the present modem include 1600Hz, 1670Hz, 1745Hz, 1828Hz, and 1920Hz. The receivers will operate with received frequency offsets of up to +/- 7Hz. A selected carrier frequency and baud rate from their respective pluralities will be established during a start up procedure after the line has been probed and the operational bandwidth thereof established. Information representing the aforementioned predetermined carrier frequencies, baud rates and data bit rates are all stored in the memory 22 for a selection under control of the controller 20 as will be more evident from the description found below.

[0022] It is understood without having to be shown or described that the present exemplary modem includes conventional interchange modem circuits which comply with the functionality and operational requirements of the V.24 recommendation of the CCITT and all such interchange circuits are adequately terminated in the corresponding data terminal equipment (DTE) and in the data circuits terminating equipment in accordance with appropriate recommendations for electrical characteristics. In addition, such modems shall accept and pass synchronous or asynchronous data from and to its corresponding DTE on the appropriate conventional inter-

change circuit and under control thereof. The timing, clocks.... etc., for example, and data rate selection switching and control are all achieved through the conventional interchange circuits.

[0023] Referring again to Fig. 3, the modem includes the following conventional signal generating functional modules: a differential phase shift keyed generator 24, a tone generator 26, a chirp signal generator 28, a train signal generator 30 and a conventional scrambler/encoder/mapper function 32 which processes the data to be transmitted. A functional switch SW1 selects the output of one of the generator modules 24, 26, 28, 30 or 32 to be an input to a transmitter/modulator functional module 34 which in turn generates a transmit signal 36. The signal 36 is conducted through a hybrid circuit 38 to the two wire connection 40 to either a leased line or dial-up line of a telephone network. The generator functions 24, 26, 28, 30 and 32 are all selected and enabled by the controller 20 via the signal path 42. In addition, the functional switch module SW1 is also controlled by the controller 20 via the switch control path 44. Still further, information related to the carrier frequency, baud rate and data bit rate along with certain control signals are provided to the transmitter/modulator 34 from the controller 20 over the data and control path 46.

[0024] Received signals are passed from the two line conductor 40 through the hybrid 38 to a combiner function 48 of the modem. A conventional echo canceller function 50 estimates an echo based on perceived characteristics of the channel in accordance information provided to it from the controller 20 via path 46. The echo canceller 50 provides the echo estimate to the combiner 48 over path 52 so that the received signal may be relieved of its echo component by the combiner 48. An echo error is provided back to the echo canceller 50 over path 54 in order to adjust the echo canceller to a more effective level.

[0025] The received signal from the combiner 48 is provided over the signal path 56 to a variety of additional functional modules of the modem including a conventional programmable tone detector module 58, a receiver/demodulator/equalizer module 60 and a DPSK receiver 62. The modem further includes a receiver initialization and control functional module 64 which initializes and controls the module 60 via the signal path 66. In addition, the tone detect module 58 and initialization and control module 64 are governed by the controller 20 utilizing the path 68. The data output of the receiver module 60 is provided to a conventional decoder scrambler module 70 over the data path 72. The module 70 processes the data received.

[0026] Still further, the modem includes a counter 74 which is used to compute the range MT or NT, as the case may be, which will become more evident from the description found below. The counter 74 may be started by the controller 20 using path 76 and stopped by the receiver 60 using path 78.

[0027] In the present embodiment, a conventional Fast Fourier Transform FFT processor 80 operates on the received signals at selected times to estimate channel characteristics and select a communication parameter combination of carrier frequency, baud rate and data bit rate under control of the controller 20 via data path 82. The resulting parameter combination is provided to a decision logic function 84 over the data path 86. In addition, the selected communication parameter of the remote modem are received by the DPSK receiver 62 and provided to the decision logic module 84 using the path 88. The decision module 84 decides the carrier frequency, baud rate and data bit rate for use by the modem based on estimated characteristics of the channel over which it is communicating with another modem. If the decisional module 84 cannot find a carrier frequency and baud rate consistent with a desired maximum and minimum bit rate range set by the controller 20, then it generates an error signal (ERROR). The combined carrier frequency, baud rate and data bit rate information and ERROR signal are all provided from the decisional logic module 84 to the controller 20 over the signal path 90 for storage in the memory module 22 thereof.

[0028] The foregoing described modem may be controlled to initiate a call and thus, be operated in a call mode (hereinafter referred to as a call modem) or may be controlled to answer a call, and thus, be operated in an answer mode (hereinafter referred to as an answer modem).

[0029] An example of operation of the preferred modem embodiment described in connection with the schematic block diagram of Fig. 3 will now be supplied in connection with the communication between a call/answer two wire modem pair which intend to communicate over a communication media such as a lease line or dial-up line of a telephone network like that described in connection with the network models of Figs. 1 and 2, supra. The signal flow illustrations of Figs. 5 - 12 depict the "handshaking" signal exchange between a call and answer modem pair for start up training and the initiation of retraining during conventional data transmission therebetween. Further, Figs. 13A - 13D represents suitable software programming to embody the functional modules of the call modem and Figs. 14A -14D depict flowcharts of software programming suitable for embodying functional modules of the answer modem.

[0030] To start with, references are made to Figs. 3, 5, 13A and 14A for purposes of describing a common start up procedure which includes line probing the telephone line connection communication media between the call and answer modems to learn the channel characteristics in estimating the round trip delay from each modem, referred to as ranging. After a call is initiated from a call modem, the answer modem on connection to the line, shall transmit an answer back tone as recommended by V.25 and then commence transmitting a pilot tone P1 as shown in Fig. 5 and flowchart block 100. To accomplish this, the controller 20 selects and enables the tone generator 36 to generate a tone at 400 and

2800 Hz (P1) and controls the switch SW1 to pass the generated tone to the transmitter/modulator 34 which transmits the tone overpath 36 through the hybrid 38 and out over the two wire line 40 to the call modem. Concurrently, in block 100, the controller 20 of the answer modem initializes the module 58 for the reception of a tone at 1600Hz (P2). At this time, both modems may be set at the symbol timing of 2400 Hz.

[0031] Simultaneously, the call modem similarly governs the transmission of the P2 tone and initializes its module 58 to receive and detect the P1 tone according to block 102. After receiving the answer back tone for at least 1 second or upon a reception of the P1 tone as detected by the module 58 in accordance with block 104, the call modem waits for at least 128 timing periods (at a symbol timing T of 2400Hz) and then transmits the phase reversal tone $\overline{P2}$ for a period of 16T by controlling the tone generator 26 and transmitter/modulator 34 (block 110). Concurrently therewith, the controller 20 of the call modem starts the NT counter 74. Thereafter in the flowchart block 112, the call modem initializes the detect module 58 to detect the phase reversed tone $\overline{P1}$ and controls the transmitter 34 to transmit all zeroes. Then looks for the phase reversal tone $\overline{P1}$ in the decisional block 114.

[0032] After receiving the P2 tone (block 106), the answer modem initializes its detect module 58 in block 108 to detect the phase reversal tone P2 .

[0033] The answer modem then looks for the phase reversal tone P2 in the decisional block 116 and when it receives and detects the tone $\overline{P2}$ by the module 58, it executes the flowchart block 118 which causes the controller 20 to wait for at least 64T, and then control the tone generator 26 and transmitter 34 to transmit a phase reversal tone $\overline{P1}$ for 16T. Thereafter, in the block 120, the controller 20 of the answer modem initializes the FFT processor 80 to compute the channel characteristics estimation resulting from received echo signals.

[0034] In the call modem, when the tone $\overline{P1}$ is detected as determined by functional block 114, the MT counter 74 is stopped by the receiver module 60 according to the instructions of block 122 and the FFT processor 80 thereof is initialized to compute an estimation of channel characteristics from a received signal. The resultant digital count of the MT counter 74 is representative of the round trip delay or range between the two modems and is stored in the memory 22 by the controller 20 for later use in controlling the echo canceller 50.

[0035] In the present state, both the call modem and answer modem are initialized to estimate channel and noise characteristics which is accomplished by one modem transmitting a known broad band signal, such as a chirp signal and, at the same time, receiving the echo signal therefrom, while the other modem at the remote end receives the chirp signal. Both modems, estimate the channel and noise characteristics from their respective receive signals.

[0036] In the present embodiment, according to the flowchart block 124, the controller 20 of the answer modem controls the chirp generator 28, switch SW1 and transmitter 34 to transmit a line probing chirp signal which is a periodic signal comprised of a series of tones spaced at 37.5 Hz apart within a frequency band of approximately 100 - 3600 Hz. Within this frequency band, 3 nulls are transmitted in place of the tones where one measures the nonlinear distortion, if any, introduced by the channel of the communication media. The line probing chirp signal repeatedly transmitted at least 64 times for approximately 1.8 seconds by the answer modem during which time it is receiving echo signals which are conducted to the FFT processor 80 and analyzed for estimating echo characteristics of the communication media.

[0037] Similarly, the instructions of block 126 cause the controller 20 of the call modem to activate the FFT processor 80 to perform and analyze the received line probing chirp signal from the answer modem for estimating the signal characteristics of the communication media. Each receiving modem estimates its respective media characteristics of the broad band signal by averaging its spectrum over 64 periods which is the number of chirp signal periods being generated. Averaging over 64 periods by the FFT processor, provides about 18db of noise rejection which just about cancels out any random noise leaving behind only the known transmitted signal or echo signal linearly and nonlinearly distorted by the channel. The functional block diagram schematic of Fig. 4 offers a series of modules suitable for embodying an FFT processor for performing the estimation of signal or echo characteristics of the communication media.

[0038] Referring to Fig. 4, the incoming tones of the line probing chirp signal or echo signal thereof, as the case may be, are gathered in the block 130 and saved in a temporary memory buffer according to the functional block 132. Since the channel may introduce a frequency offset which could make the received signal non-periodic, a frequency offset correction is accomplished, using the frequency offset of block 134 and mixer 136, prior to computing the Fourier transform thereof.

[0039] A 256 point FFT processing algorithm 138 is used, in the present embodiment, for computing the received signal to noise ratio over a predetermined frequency spectrum or a received signal to echo ratio over the same predetermined frequency spectrum. For this computation, 512 time samples or points are gated through the gate 140 at a time as governed by the time window signal 142 to the FFT 138. A power signal spectrum is computed for each of the 64 periods over the 1.8 second interval by the FFT processor 138 and stored in an accumulator 144. A timing offset correction TOFF and a frequency offset correction ROT are introduced to each result out spectrum. The individual spectrums are then averaged to yield an overall resultant spectrums to either reduce or eliminate random noise. Also in block 144, the resultant average power spectrum is

squared to yield a squared spectrum which is subtracted from the original spectrum to yield a channel noise spectrum. The output of the block 144 provides both a signal power spectrum and a noise power spectrum to a combiner block 146. The nonlinear distortion introduced by the channel is also measured in block 148 by averaging the energy at the null points of the signal spectrum which were introduced by the line probing signal. A block 150 is used to hunt for an optimum carrier frequency based on the resultant spectrums.

[0040] Since the goal of the FFT processor is to maximize the data bit rate for a particular channel according to the estimated characteristics thereof, the number of bits per baud that can be transmitted through the channel and received by the modem receiver for a given BER is calculated. A 2-tap DFE model is constructed and based on the channel noise spectrum, the noise at the output of the DFE model, for unit signal is also calculated. The DFE model (linear) noise, the nonlinear noise and the signal level of the various spectrums are weighted and combined in block 146 to obtain the total noise at the input of the receivers decoder. The signal to noise ratios are established in blocks 152 and 154. In block 156, the total noise including distortion above the received and echo signals are computed and scaled to unity. In block 158, the bits/baud is then computed from a fourier series approximation of the decoders signal to noise ratio. Resulting from block 158 is an optimum carrier frequency baud rate, and data bit rate within the desired data bit rate range provided from the controller 20. In block 160 the resultant information is packed in a particular format for providing it to the other modem as will be fully understood from the description herebelow.

[0041] In the decision logic block 84, a final decision algorithm chooses between the selected and received parameters of carrier frequency, baud rate and data bit rate in accordance with a predetermined criteria. The criteria used by the present embodiment in choosing between the selected and received carrier frequencies baud rates and data bit rates, is one of less than or equal to, respectively.

[0042] After the answer modem completes the 1.8 second line probing signal generation, it completes the instructions of block 124 by disabling the chirp generator 28 and controls the tone generator 26, switch SW1 and transmitter 34 to commence transmission of the tone P1 for at least 128T. Thereafter, the controller 20 of the answer modem initializes the module 58 for the detection of the tone P2 and then waits in the decisional block 164 for the reception and detection thereof. In addition, after the call modem completes the channel estimation of block 126 for the received line probing signal, the controller 20 in response to the instructions of block 166 initializes the module 58 for the detection of tone P1 and waits for the tone P1 to be detected according to the decisional block 168. During this time, the call modem is continuing transmission of zeroes. Upon detection of the tone P1 by the module 58, the controller 20 of the call modem terminates the zero transmissions by controlling the transmitter 34 and generates the tone P2 by controlling the tone generator 26, switch SW1 and transmitter 34. At the same time, the controller 20 of the call modem initializes the module 58 for the detection of the phase reversal tone $\overline{P1}$ according to block 170. In block 172, the controller 20 of the call modem waits in a loop for the detection of the tone $\overline{P1}$ by the module 58.

[0043] When the tone P2 is detected by the module 58 of the answer modem, the controller 20 thereof responds to the instructions of block 174 and initiates transmission of the phase reversal tone $\overline{P1}$ for 16T and concurrently starts the NT counter 74. Moreover, the instructions of block 176 cause the controller 20 of the answer modem to initialize the module 58 for the detection of the tone $\overline{P2}$ after 16T and, then, cause the transmitter to transmit zeroes during which time it waits in a decisional loop according to the block 178 for the reception and detection of the tone $\overline{P2}$. After $\overline{P1}$ is detected by the module 58 of the call modem (block 172), block 180 is executed by the controller 20 thereof which governs the transmission of the tone $\overline{P2}$ for 16T after waiting for a delay period of 64T. Concurrently, the controller 20 of the call modem initializes its FFT processor to perform an estimation of channel characteristics based on received echo signal or signals. The detection of tone $\overline{P2}$ by the answer modem causes the receiver 60 thereof to stop the NT counter 74, and the controller 20 to initialize the FFT processor 80 thereof to perform a channel estimation based on the received line probing chirp signal. In blocks 184 and 186, the same line probing process is performed as described supra except that the call modem now is transmitting the line probe chirp signal and performing the estimated channel characteristics based on the echo signal thereof and the answer modem is performing the estimation of a channel characteristics based on the received line probing chirp signal. In the present embodiment, this channel estimation line probing procedure takes approximately 1.8 seconds.

[0044] After performing the second line probing task, the selected carrier frequency, baud rate and data bit rate of each of the call and answer modems are provided to their respective controller 20 which in turn selects and enables the respective DPSK generator 24 to generate the learned information in packets or frames to the other modem via switch SW1 and transmitter 34. In the block 190, the controller 20 of the answer modem is directed to initiate the DPSK receiver 62 for the detection of the transmitted DPSK2 frames from the call modem.

[0045] In the present embodiment, a 300 baud DPSK modulation scheme is used to exchange the communication parameter information between the call and answer modems. A carrier frequency of 1200 Hz is used for DPSK transmission. The DPSK carrier is stored in memory of the controller 20. The data to be sent is encoded and modulated by governing the generator 24 by the controller 20 and sent out over the line 40. Since the above method of modulation (by square wave) may pro-

duce a lot of out of band energy, the carrier frequency may be stored as a digital prolate spherical wave function, to maximize the energy in a narrower band. The DPSK receiver 62, in each case, recovers the timing of the signal, demodulates and decodes it and unpacks the information from the remote modem. The information transferred between the modems consists of the bit rate index for each baud rate, the carrier frequency for each baud rate, the baud rate mask to indicate which baud rate is disabled by the host, symmetric bit rate flag and symmetric baud rate flag.

[0046] After the answer modem detects the carrier of the DPSK2 signal according to block 192, the instructions of block 194 are then executed governing the controller 20 to terminate zero transmission and transmit the DPSK1 information while receiving the DPSK2 information. The call modem shall now look for the DPSK1 carrier from the answer modem and then, after detecting two frames of DPSK1 information, shall stop transmitting the DPSK2 data and go to an idle state for approximately 20T and then change its carrier frequency and baud rate to the one recommended by the preceding line probing procedure. Accordingly, when the answer modem detects loss of carrier from the call modem it also goes to an idle state for approximately 20T and thereafter sets its carrier frequency and baud rate to that recommended by the decisional logic block 84 of the preceding line probing procedure.

[0047] Note that according to the above described method in connection with Fig. 5 the processes of estimating channel characteristics and estimating range for the call modem to communicate with the answer modem are combined in a common start up procedure characterized by a plurality of successive time segments. For example, there is a time segment estimating the range NT of the call modem, another time segment for estimating signal characteristics of a channel for the call modem while concurrently estimating echo characteristics of the channel for the answer modem, another time segment for estimating range NT of the answer modem and yet another time segment for estimating signal characteristics of the channel for the answer modem all concurrently estimating echo characteristics of the channel for the call modem. In the present embodiment, these four time segments are performed successively. The foregoing described method also provides for a fifth successive time segment in which the call and answer modems exchange learned information for making final decisions.

[0048] The next portion of the start up procedure to be described (see Fig. 6) is a training sequence for training the receiver and echo canceler of each of the call and answer modems. This training sequence is considered well known and outlined in the V.32 and V.32bis specifications and not considered in any way a part of the present invention except that the training sequences are performed based on the recommended carrier frequency and baud rate learned from the preceding portion of the start up procedure described in connection with Fig. 5. Thus, the description of this procedure will not require great detail, but rather just a brief overview. The procedure for the most part is currently being used in the modem 2264 marketed by Codex Corporation. Portions of the procedure are also described in the U. S. Patent 4,987,569 issued January 22, 1991 and assigned to the same assignee as the present application. In describing this procedure reference will be made to Figs. 3, 6, 13B and 14B. With regard to the functional block diagram embodiment of Fig. 3, the ECQT and CHIRP signals are generated by the chirp generator 28, the TRN signal is generated by the train generator 30 and the rate signals R1, R2 and R3 are generated by a tone generator as are the tone signals S and $\bar{S}$. (Please confirm?)

[0049] Starting with the answer modem, after the carrier frequency and baud rate have been changed to the preferred numbers, an optional task IR may be performed to calculate a second or third far end echo of the network for use in echo cancellation. In the present embodiment, this task is not contemplated. The next task is the echo canceller quick train (ECQT) which is performed in accordance with the instructions of block 204. More specifically, a special chirp signal is transmitted by the answer modem for approximately 2 NT and a fast train or instantaneous train of the echo canceller thereof is performed based on the echo of the chirp signal. In block 206, a tone signal S is transmitted for approximately 256T and then the phase reversal $\bar{S}$ is transmitted for a 16T. Immediately thereafter, a special chirp sequence which is used to quickly train the equalizer of block 60 of the receiver is transmitted for 144T. Next, in block 208 a signal TRN is transmitted for 2048T which is used by the call modem to further train the equalizer of block 60 and the echo signal thereof by the answer modem to further train its echo canceller. Thereafter, a special rate signal R1 is transmitted and during this time the answer modem waits to detect an S signal from the call modem in the decisional block 210. When the S signal is detected, the rate signal R1 transmission is terminated and the answer modem commences transmitting zeroes according to the instructions of block 212. The answer modem then determines whether or not the S signal exists longer than or equal to MT and if so, it initializes itself for detection of the phase reversal $\bar{S}$ signal in blocks 214 and 216. During this time the answer modem is continuing to transmit zeroes. Once the signal $\bar{S}$ is detected in the decisional block 218, the block 220 is next executed to initialize the answer modem to perform an equalizer fast train with the received chirp signal from the call modem for 144T according to a well known DFT algorithm. Thereafter, the answer modem performs a further equalizer training according to a well known least means square (LMS) algorithm for 2000T based on the received TRN signal from the call modem in block 222.

[0050] In the next instruction block 224, the answer modem initializes itself for the detection of a special rate

signal R2 transmitted from the call modem. Once the signal R2 is detected in block 224, the next instructional block 228 is executed and causes the answer modem to transmit first the S tone for 256T, second the $\bar{S}$ tone for 16T, and then the TRN training signal for 512T. Thereafter, according to the instructions of block 230, the answer modem commences transmission of a special rate signal R3 which includes the information of a selected communication rate upon which both call and answer modems can agree on, i.e. common to both based on the maximum rate that they can operate at. At the same time, the answer modem initializes itself for the detection of a signal E1 indicative of the call modem agreeing to the selected rate. Once the signal E1 is detected in the decisional block 232, the answer modem terminates the transmission of the rate signal R3 and transmits the signal E2 for 8T which is an indication to the call modem that the selected rate is accepted. Thereafter, the answer modem transmits a frame of channel coefficients CC2 for 64T according to the instructions of block 236 and then transmits scrambled binary zeroes B1 for 256T according to the instructions of block 238, followed by the transmission of a flag F2 composed of a predetermined baud/bit pattern. Thereafter, the answer modem is enabled for exchange of data based on the recommended carrier frequency, baud rate and data bit rate determined in the foregoing described learning process.

[0051] Concurrently, the answer modem, after transmitting the E2 sequence according to block 234, initializes itself to detect channel coefficients CC1 from the call modem in block 242. Once the signal CC1 is detected according to the decisional block 244, the answer modem initializes itself for the detection of a flag F1 in block 245. Once the signal F1 is detected according to the decisional block 246, the answer modem initializes itself to receive data and receives data based on the recommended rates in blocks 248 and 250.

[0052] Now for the call modem. After setting the selected parameters in block 202, the call modem waits in a loop according to the decisional block 252 to detect an incoming S signal sequence from the answer modem in order to proceed with the training of its receiver and echo canceller. After detecting the S signal, the call modem initializes itself to detect the $\bar{S}$ signal in block 254 and waits for reception of the $\bar{S}$ signal in block 256. After $\bar{S}$ is detected, the call modem initializes itself for and performs an equalizer fast train utilizing the chirp signal transmitted by the answer modem for 144 T which is accomplished according to the instructions of block 258. Thereafter, the call modem performs an equalizer training according to a least mean square (LMS) algorithm for 2,000 T using the received TRN signal from the answer modem using the block 260. Next, in block 262, the call modem initializes itself for detection of the rate signal R1 and waits in a detection loop at decisional block 264 looking for three consecutive frames which identically match in order to start transmitting the S signal sequence. Upon detection of R1 by block 264, the call modem, in block 266, transmits an S sequence for a period equal to the round trip delay measurement MT. The IR task segment may be included in the procedure at this time. Thereafter, in block 268, the call modem may transmit the echo canceller conditioning signal for a period of 2 MT in order to perform a fast train echo canceller task based on the received echo signal therefrom. Next, in block 270, the transmitter of the call modem shall transmit an S sequence for a period of 256 T, followed by a phase reversal sequence for 16T. The phase reversal serves as a time marker to train the equalizer. The transmitter next transmits a periodic CHIRP sequence for 144 T as part of the receiver conditioning signal.

[0053] In block 272, the call modem transmits the TRN signal segment which is a sequence of scrambled binary 1's for a period of 2048 T, and then commences transmission of a rate signal R2 to indicate the available data rates in the call modem. The signal R2 takes into account the previously received rate signal R1 and may also take into account the likely receiver performance for the connection. If the connection is unacceptable, the call modem may transmit a GSTN clear down code. The transmission of R2 shall continue until the reception and detection of the incoming rate signal R3 from the answer modem. During the R2 transmission, the call modem detects the signal S from the answer modem in the decisional block 274 and initializes for the S/ $\bar{S}$ time mark transition in the block 276 and waits for the time mark detection in the decisional block 278. Once the transition is detected, block 280 is executed to govern the reception of the TRN signal from the answer modem for use in fine tuning the receiver of the call modem and then the call modem is initialized for the rate signal R3 detection. The call modem waits for R3 detection in the decisional block 282 and once detected, the call modem transmits a 16 bit sequence E1 indicating it agrees with the data rate information provided it by the answer modem in the rate signal R3.

[0054] After transmission of the E1 sequence, the call modem transmits one frame of channel coefficients CC1 for 64 T in block 286 and then transmits scrambled binary zero's B1 for 256 T in block 288. Thereafter, in block 290, the call modem is governed to transmit a flag F1 composed of a dibit pattern 11, and then proceed to transmit data at the agreed upon rates of the E sequence. The scrambler and encoder 32 is initialized at this time. If, however, the rate signal R3 calls for a GSTN clear down, the call modem disconnects from the dial line and effects a clear down.

[0055] Concurrently with the transmission of the CC1 signal, the call modem is initialized to detect the E2 sequence from the answer modem in block 292. Once E2 is detected in the decisional block 294, the call modem is initialized for the detection of the channel coefficients CC2 from the answer modem in block 296. When CC2 is detected in the decisional block 298, the call modem

is initialized for the detection of the flag F2 in block 300. After the flag F2 is detected in block 302, the call modem is initialized in blocks 304 and 306 to receive data and receive data according to the preferred parameters previously learned.

[0056] During the period of data communication over the communication media between the call and answer modems, a retrain request may be initiated by either modem for a plurality of reasons. For example, if either modem detects unsatisfactory signal reception, like loss of equalization, for example, a retrain shall be initiated to reassess the connection which may or may not include the line probing learning process. Another reason may be if either of the modems determines that the quality of the connection is good enough to attempt to increase data bit rate for which only a quick retrain may be needed. In the present embodiment, a tone using the signal states A, B, C, and D is used to initiate retraining and request the desired start up procedure. The signal states A, B, C, and D are separated by 90 degrees and reside at the respective phases 210, 300, 30, and 120 for the present embodiment. In describing the retraining procedures in accordance with the present invention, reference will be made to FIGS. 7-12, 13D and 14D. In the modem embodiment described in connection with FIG. 3, the tone generator 26 will generate the tones and the tone detect module 58 shall be programmed to receive and detect the tone sequences in accordance with instructions from controller 20.

[0057] FIG. 7 represents a time segmented signal flow between a call and answer modem in which retrain and line probing are initiated and requested, respectively, by the call modem. Initially, both of the call modem and answer modem are exchanging data according to blocks 310 and 312 and are waiting in a loop to determine whether or not to request a retrain in decisional blocks 314 and 316. When the call modem detects an unsatisfactory signal reception, it shall transmit the tone in the sequence ADCB in block 318 and wait in a loop in accordance with the decisional block 320 for the detection of the signal sequence ABCD from the answer modem. Concurrently, the answer modem is waiting for reception of the signal sequence ADCB in decisional block 322 and when that signal sequence is detected, the answer modem delays for a period of at least 128 T in block 324 and then transmits the signal sequence ABCD for at least a period of 256 T in block 326.

[0058] When the call modem detects the sequence ABCD in the decisional block 320, it decides whether or not it desires a line probe retrain in block 328. Since this is the case in the present example, the call modem terminates transmission for a period of approximately 20 T and then changes its symbol clock T to 2400 Hz to begin executing at the start of the program described in connection with FIG. 13A commencing with the transmission of the tone P2 in block 102. Since the answer modem is not requesting a line probe retrain, its decision of block 330 causes program flow to execute the instructions of block 332 which initiates transmission of the signal sequence BCDA. During the time the answer modem is transmitting the signal sequence BCDA, it awaits detection of either a signal sequence DCBA or the tone P2 in the decisional block 334 or the detection of a loss of carrier in the decisional block 336. In the present case, the detection of the tone P2 returns the program to the start of the programming sequence described in 14A with the commencement of the tone P1 after a predetermined period of silence. Thereafter, the line probing and ranging training tasks are carried out in accordance with the instructions of FIGS. 13A-C and 14A-C as described hereabove.

[0059] In the example of FIG. 8, the call modem initiates the retrain procedure, but the answer modem requests the line probing training sequence. In this example, the call modem will execute the blocks 310, 314, 318, and 320 as described above and similarly the answer modem shall execute the blocks 312, 322, 324, and 326. But since the answer modem is the modem which is requesting the line probe retrain, it shall transfer its program execution via the decision block 330 to the start of the program of FIG. 14A wherein it commences transmission of the tone P1 after ceasing transmission for approximately 20 T. The modulation clock T is changed to 2400 Hz for the transmission for the tone P1. The call modem awaits the detection of either the tone sequence B, C, D, A or the tone P1 in the decision block 340 as well as a loss of carrier in the decision block 342. In the present case, when the tone P1 is detected, the call modem transfers program execution to the start of the training sequence of FIG. 13A in which it commences transmission of the tone P2 in block 102 after a silence period of approximately 20 T. Note that the modulation clock is changed to 2400 Hz for the transmission of the tone signal P2. Thereafter, the call modem and answer modem will proceed through the training sequence of FIGS. 13A and 14A.

[0060] In the example of FIG. 9, the call modem is initiating retraining most likely as a result of the possibility that the quality of the line connection is good enough to sustain a higher data bit rate, but no line probing training sequence is requested. Once again, the call modem executes the blocks 310, 314, 318, and 320 and the answer modem executes the blocks 312, 322, 324, and 326. When the call and answer modems reach the decisional blocks 328 and 330, respectively, neither is requesting a line probe retrain. Therefore, the answer modem transmits the tone sequence B, C, D, A in block 332 and starts the range counter NT. Thereafter, the call modem detects the tone sequence BCDA in block 340 and delays for a period of 256 T +/- 2 T in block 344. During the delay, the call modem tests for carrier loss in block 346 and if carrier loss is detected, program execution is transferred to the start of the program of FIG. 13A. With no carrier loss and after the delay of 256 T, the call modem transmits the tone sequence D, C, B, A in block 348 and awaits the detection of the tone se-

quence C, D, A, B from the answer modem in the decisional block 350. In turn, the answer modem detects the tone sequence D, C, B, A in block 334 and stops the range counter to compute the range NT in block 352. The answer modem next waits for a delay of 256 T +/- 2 T and then transmits the tone sequence C, D, A, B. In decisional block 354, the answer modem awaits detection of the tone sequence D, C, B, A from the call modem. Concurrently, upon the transmission of the tone sequence D, C, B, A in block 348, the call modem starts its range counter MT and with the detection of the tone sequence C, D, A, B in block 350, the call modem terminates transmission of the tone sequence D, C, B, A and computes the range MT in block 356. Thereafter, the program execution of the call modem is transferred to the start of the quick retrain sequence of FIG. 13B omitting the line probing and ranging tasks of Fig. 13A. Simultaneously, the answer modem detects the tone sequence D, C, B, A in block 354 and terminates transmission for the tone sequence C, D, A, B in block 355 and returns program execution to the retrain sequence at the start of the program of FIG. 14B also omitting the line probing and ranging tasks of Fig. 13B.

[0061] In the examples of Figs. 10, 11 and 12, the answer modem is the modem which is initiating a retraining sequence. The example of Fig. 10 is one in which the answer modem detects an unsatisfactory signal reception and not only terminates data communication, but also initiates both retrain and line probing sequences. Referring to Fig. 10, the blocks 312 and 316 are executed resulting in the transmission of the tone sequence ABCD in accordance with the instructions of block 358. The answer modem then waits for the reception and detection of the tone sequence ADCB from the call modem in the decisional block 360. Simultaneously, the call modem is awaiting detection of the tone sequence ABCD in the decisional block 362 and when detection is made, a delay of at least 128T is activated in block 364 and thereafter, the call modem transmits the tone sequence ADCB in block 366. Upon detection of the tone sequence ADCB in block 360, the answer modem, which is not requesting line probe retrain, executes the block 332 next to cause the transmission of the tone sequence BCDA after a delay of approximately 256T and then waits for the detection of either the tone sequence DCBA or the tone P2 in the decisional block 334 or loss of carrier (block 336). Concurrently, since the call modem is requesting a line probe retrain, program execution is diverted from the decisional block 328 to the start of the program in Fig. 13A in which the tone P2 is transmitted after a silence period of approximately 20T. The symbol for modulation clock is changed for the transmission of P2 to 2400Hz. When the answer modem detects the tone P2 in the decisional block 334, it diverts program execution to the start of the program of Fig. 14A in which the tone P1 is transmitted after a silence period of approximately 20T at the new symbol or modulation clock of 2400Hz. Thereafter, both the answer and call modems continue program execution as described in connection with Figs. 13A and 14A.

[0062] In the example of Fig. 11, it is the answer modem that is requesting a line probe retrain; therefore, after detecting the tone sequence ADCB in the decisional block 360, the answer modem diverts the program execution via block 330 to the start of the program of Fig. 14A as described hereabove. When the call modem detects the tone P1 in the decisional block 340 it diverts program execution to the start of the program of Fig. 13A after delaying for a period of 64T. Thereafter, both the call and answer modems operate in accordance with the program execution of Figs. 13A and 14A.

[0063] In the example of Fig. 12, no line probe retrain is requested by either the call and answer modem. Therefore, the call and answer modems shall go through the same sequence for computing their respective ranges MT and NT as described hereabove in connection with the example of Fig. 9. Thereafter, program execution for both the call and answer modem will proceed starting at the Figs. 13B and 14B omitting the training sequences of Fig's. 13A and 14A.

[0064] Another aspect of the present invention involves the data communication between a call and answer modem over a primary communication media connection, like a leased line of a telephone network, for example, wherein a failure in the connection is detected. Normally, the primary connection would be switched to a secondary connection like a dial-up line of a telephone network as part of the GSTN. However, in the case in which the carrier frequency, baud rate and data bit rate parameters of the communication have been optimized in accordance with the above described learning process, it is not adequate to select any secondary connection, but rather important to prequalify the connection so as to maintain the optimum parameters in continuing data communication between the call and answer modems.

[0065] Therefore, this aspect of the present invention deals with prequalifying a secondary connection of a predetermined plurality of secondary connections with regard to the optimized communication parameters prior to affecting the switch over. Likewise, when operating over the qualified secondary connection, it is desirable to test and qualify the primary connection in order to restore communication over the primary connection at some later time. This method shall be described in connection with the flowchart of Fig. 15. The process of switching from a primary connection to a secondary connection and restoring the primary connection is considered well known and will not be described in detail in the instant application.

[0066] Referring to Fig. 15, the method starts in the decisional block 370 where it is determined whether or not there is a failure in the primary communication media connection over which the call and answer modems are presently communicating. When a failure is detected, the block 372 is next considered in which a first of the

plurality of secondary connections is qualified according to the embodiment described in Fig. 5 and flowcharts Figs. 13A and 14A. If it is determined that the selected secondary selection can support communication at the desired combination of carrier frequency, baud rate and data bit rate, it is accepted by the decisional block 374; otherwise, the next secondary connection of the plurality is qualified and determined whether or not acceptable according to the same criteria in block 376. Once the secondary connection is accepted, communication between the call and answer modems are switched to the secondary connections from the primary connection in block 378 and thereafter, communication continues over the accepted secondary connection. Thereafter, the primary connection is tested and qualified in accordance with the same procedures, i.e. Fig. 5 and Figs. 13A and 14A, in block 380. And if found to support the aforementioned combination of communication parameters at some later time, the primary connection is considered accepted by decisional block 382 and as a result of the acceptance, communication between the call and answer modems is restored to the primary connection in block 384. And the method procedure continues back at the decision block 370 as described hereabove.

[0067] It is understood that in connection with this last aspect of the present invention, the call and answer modems might may be either 2 or 4 wire modems, however, in the case of a 4 wire modem there is no need for considering channel characteristics with respect to echo transmissions. Therefore, that part of the learning sequence may be omitted.

Claims

1. A two-wire modem for communicating with a remote modem over a communication medium, the two-wire modem having a transmitter for transmitting signals onto the communication medium, a receiver for receiving signals from the communication medium; a line probing processor for sending and receiving line probing signals, and an echo canceller for cancelling echoes in the communication medium, the two-wire modem **characterized in that** the line probing processor comprises:

   means (34) for transmitting for a first predetermined time interval a first line probing signal of varying frequency content over said communication media;
   means (38) for receiving at least one echo signal of said first line probing signal from said communication media in said first predetermined time interval;
   means (38) for receiving a second line probing signal of varying frequency content from said communication media in a second predetermined time interval;
   means (80) for estimating signal characteristics of the communication medium based on an analysis of said received second line probing signal;
   means (50) for estimating echo characteristics of the communication medium based on an analysis of said received at least one echo signal of said first line probing signal; and
   means (84) for selecting a carrier frequency and a baud rate from among a plurality of carrier frequencies and baud rates based on said estimates of the signal and echo characteristics of the communication medium.

2. The two-wire modem in accordance with claim 1 wherein:

   the estimating means (50) includes means for computing a signal-to-noise ratio over a predetermined frequency spectrum from said received second line probing signal and an echo-to-noise ratio over the predetermined frequency spectrum from said received at least one echo signal and, where selected, the means for computing includes a Fast-Fourier Transform (FFT) processor; and wherein the selecting means (84) includes means for determining at least one desirable communication frequency band of the communication media within the predetermined frequency spectrum based on the computed signal-to-noise and echo-to-noise ratios and for selecting the carrier frequency and baud rate based on said at least one desirable communication frequency band.

3. The two-wire modem in accordance with claim 1 wherein the first and second line probing signals include a chirp signal ranging from a first frequency to a second frequency which is repeated a plurality of times over said respective first and second predetermined time intervals; and wherein the estimating means (50) include means for estimating an average of the signal characteristics, based on an analysis of the repetitive chirp signal of the second line probing signal, and means for estimating an average of the echo characteristics, based on an analysis of the repetitive chirp signal of the echo of the first line probing signal.

4. The two-wire modem in accordance with claim 1 wherein the selecting means (84) includes means for selecting the carrier frequency and baud rate based also on at least one desired data bit rate.

5. The two-wire modem in accordance with claim 1 wherein the estimating means includes means (80) for estimating signal characteristics, including non-linear signal distortion of the communication media;

and means for estimating echo characteristics, including non-linearities in at least one echo path of the first line probing signal in the communication media.

6. The two-wire modem in accordance with claim 4 wherein the means (84) for selecting the carrier frequency and baud rate includes means for receiving information from the other modem, said information including a carrier frequency, a baud rate and a data bit rate at which the other modem expects to communicate, and means for deciding which of the selected and received carrier frequency, baud rate and data bit rate will be ultimately used by the two-wire modem in communicating with the other modem over the communication media.

7. A method of selecting a carrier frequency and a baud rate for communication between a call modem and an answer modem over a channel of a communication media, the channel introducing a round trip delay, also referred to as range, between the call modem and the answer modem, said carrier frequency and baud rate selected during a common start up procedure having a plurality of successive time segments, the method **characterized by** the steps of: >

transmitting (34) a first signal of varying frequency content over said channel in one time segment;
receiving (38) at least one echo signal of said first signal from said channel;
receiving (38) a second signal of varying frequency content over said channel in a second time segment;
estimating (122) a range for one of the call and answer modems in said one time segment of the plurality of successive time segments of the start up procedure;
estimating (124) signal characteristics of the channel for the one modem based on an analysis of said received second signal in said second time segment of said plurality while concurrently estimating echo characteristics of the channel for the other of the call and answer modems based on said received at least one echo signal of said first signal;
transmitting (34) a third signal of varying frequency content over said channel in a third time segment;
receiving (38) at least one echo signal of said third signal from said channel;
receiving (38) a fourth signal of varying frequency content over said channel in a fourth time segment;
estimating (182) a range for the other modem in said third time segment of said plurality; and
estimating (184) signal characteristics of the channel for the other modem based on an analysis of said received fourth signal in said fourth time segment of said plurality while concurrently estimating echo characteristics of the channel for the one modem based on said received at least one echo signal of said third signal;
selecting a carrier frequency and baud rate for the call modem based on the estimated signal and echo channel characteristics thereof; and
selecting a carrier frequency and baud rate for the answer modem based on the estimated signal and echo channel characteristics thereof.

8. The method in accordance with claim 7 wherein the one, second, third and fourth time segments are successive in the start up procedure and wherein the one modem is the call modem and the other modem is the answer modem.

9. The method in accordance with claim 7 including the steps of:

exchanging the information of respective carrier frequency and baud rate over the communication media between the call and answer modems; and
determining a carrier frequency and baud rate for each of the call and answer modems from the selected and exchanged carrier frequencies and baud rates, respectively.

10. The method in accordance with claim 7 further including the steps of:

training a receiver and echo canceller of each of the call and answer modems by exchanging signals therebetween over the communication media at the respective determined carrier frequency and baud rate thereof; and
exchanging data between the call and answer modems over the communication channel at the respective determined carrier frequency and baud rate thereof.

Patentansprüche

1. Ein Zweidrahtmodem zur Kommunikation mit einem entfernten Modem über ein Kommunikationsmedium, und das Zweidrahtmodem einen Übertrager zur Übertragung von Signalen in das Kommunikationsmedium, einen Empfänger zum Empfang von Signalen aus dem Kommunikationsmedium, einen Prozessor zur Leitungsprüfung zum Senden und Empfangen von Leitungsprüfsignalen und einen Echobeseitiger zur Beseitigung von Echos im Kommunikationsmedium hat, und das Zweidraht-

modem **dadurch gekennzeichnet ist, dass** der Prozessor zur Leitungsprüfung folgendes aufweist:

Mittel (34) zur Übertragung eines ersten Leitungsprüfsignals mit veränderlichem Frequenzgehalt über das Kommunikationsmedium in einem ersten vorherbestimmten Zeitintervall;

Mittel (38) zum Empfang von wenigstens einem Echosignal des ersten Leitungsprüfsignals aus dem Kommunikationsmedium im ersten vorherbestimmten Zeitintervall;

Mittel (38) zum Empfang eines zweiten Leitungsprüfsignals mit veränderlichem Frequenzgehalt aus dem Kommunikationsmedium in einem zweiten vorherbestimmten Zeitintervall;

Mittel (80) zur Abschätzung von Signalkenndaten des Kommunikationsmediums, basierend auf einer Analyse des empfangenen zweiten Leitungsprüfsignals;

Mittel (50) zur Abschätzung von Echokenndaten des Kommunikationsmediums, basierend auf einer Analyse des wenigstens einen empfangenen Echosignals des ersten Leitungsprüfsignals; und

Mittel (84) zur Auswahl einer Trägerfrequenz und einer Baud-Rate aus einer Vielzahl von Trägerfrequenzen und Baud-Raten, basierend auf den Abschätzungen der Signal- und Echokenndaten des Kommunikationsmediums.

2. Das Zweidrahtmodem nach Anspruch 1, bei dem:

Die Abschätzungsmittel (50) Mittel zur Berechnung eines Signal-Rausch-Verhältnisses über ein vorherbestimmtes Frequenzspektrum aus dem empfangenen zweiten Leitungsprüfsignal und eines Echo-Rausch-Verhältnisses über das vorherbestimmte Frequenzspektrum aus dem wenigstens einem empfangenen Echosignal enthalten, und, wo ausgewählt, die Mittel zur Berechnung einen Prozessor für Fast-Fourier-Transformationen (FFT) enthalten; und bei dem die Auswahlmittel (84) Mittel zur Bestimmung von wenigstens einem wünschenswertem Kommunikationsfrequenzband des Kommunikationsmediums innerhalb des vorherbestimmten Frequenzspektrums enthalten, basierend auf den berechneten Signal-Rausch- und Echo-Rausch-Verhältnissen, und zur Auswahl der Trägerfrequenz und der Baud-Rate, basierend auf dem wenigstens einen wünschenswerten Kommunikationsfrequenzbandes.

3. Das Zweidrahtmodem nach Anspruch 1, bei dem die ersten und zweiten Leitungsprüfsignale ein Zwitschersignal enthalten, das sich von einer ersten Frequenz bis zu einer zweiten Frequenz erstreckt, das eine Vielzahl von Malen über die ersten bzw. zweiten vorherbestimmten Zeitintervalle wiederholt wird, und bei dem die Abschätzungsmittel (50) Mittel zur Abschätzung eines Mittelwertes der Signalkenndaten enthalten, basierend auf einer Analyse des wiederholten Zwitschersignals des zweiten Leitungsprüfsignals, und Mittel zur Abschätzung eines Mittelwertes der Echokenndaten, basierend auf einer Analyse des wiederholten Zwitschersignals des Echos des ersten Leitungsprüfsignals.

4. Das Zweidrahtmodem nach Anspruch 1, bei dem die Auswahlmittel (84) Mittel zur Auswahl der Trägerfrequenz und der Baud-Rate enthalten, ebenfalls basierend auf wenigstens einer gewünschten Datenbitrate.

5. Das Zweidrahtmodem nach Anspruch 1, bei dem die Abschätzungsmittel (80) Mittel zur Abschätzung von Signalkenndaten enthalten, einschließlich nicht linearer Signalverzerrungen des Kommunikationsmediums, und Mittel zur Abschätzung von Echokenndaten, Nichtlinearitäten eingeschlossen, in wenigstens einem Echopfad des ersten Leitungsprüfsignals im Kommunikationsmedium.

6. Das Zweidrahtmodem nach Anspruch 4, bei dem die Mittel (84) zur Auswahl der Trägerfrequenz und der Baud-Rate Mittel zum Empfang von Informationen vom anderen Modem enthalten, und diese Informationen eine Trägerfrequenz, eine Baud-Rate und eine Datenbitrate enthalten, bei der das andere Modem erwartet, zu kommunizieren, und Mittel zur Entscheidung, welche der ausgewählten und empfangenen Trägerfrequenz, Baud-Rate und Datenbitrate letztendlich vom Zweidrahtmodem bei der Kommunikation mit dem anderen Modem über das Kommunikationsmedium verwendet wird.

7. Ein Verfahren zur Auswahl einer Trägerfrequenz und einer Baud-Rate zur Kommunikation zwischen einem anrufendem Modem und einem antwortenden Modem über einen Kanal eines Kommunikationsmediums, und der Kanal eine Umlaufverzögerung, die auch als Entfernung bezeichnet wird, zwischen dem anrufenden Modem und dem antwortenden Modem einfügt, und die Trägerfrequenz und die Baud-Rate während einer gemeinsamen Startprozedur ausgewählt werden, die eine Vielzahl von

aufeinander folgenden Zeitsegmenten hat, und das Verfahren **gekennzeichnet ist durch** die folgenden Schritte:

Übertragung (34) eines ersten Signals mit veränderlichem Frequenzgehalt über den Kanal in einem Zeitsegment;

Empfang (38) von wenigstens einem Echosignal des ersten Signals aus dem Kanal;

Empfang (38) eines zweiten Signals mit veränderlichen Frequenzgehalt über den Kanal in einem zweiten Zeitsegment;

Abschätzung (122) einer Entfernung für eines des anrufenden oder antwortenden Modems im ersten Zeitsegment aus der Vielzahl aufeinander folgender Zeitsegmente der Startprozedur;

Abschätzung (124) der Signalkenndaten des Kanals für dieses eine Modem, basierend auf einer Analyse des im zweiten Zeitsegment der Vielzahl empfangenen zweiten Signals, während gleichzeitig die Echokenndaten des Kanals für das andere des anrufenden oder antwortenden Modems abgeschätzt werden, basierend auf dem wenigstens einen empfangenen Echosignal des ersten Signals;

Übertragung (34) eines dritten Signals mit veränderlichem Frequenzgehalt über den Kanal in einem dritten Zeitsegment;

Empfang (38) von wenigstens einem Echosignal des dritten Signals aus dem Kanal;

Empfang (38) eines vierten Signals mit veränderlichem Frequenzgehalt über den Kanal in einem vierten Zeitsegment;

Abschätzung (182) einer Entfernung für das andere Modem im dritten Zeitsegment aus der Vielzahl; und

Abschätzung (184) von Signalkenndaten des Kanals für das andere Modem, basierend auf einer Analyse des im vierten Zeitsegment der Vielzahl empfangenen vierten Signals, während gleichzeitig Echokenndaten des Kanals für das eine Modem abgeschätzt werden, basierend auf dem wenigstens einen Echosignal des dritten Signals;

Auswahl einer Trägerfrequenz und einer Baud-Rate für das anrufende Modem, basierend auf den von ihm abgeschätzten Signal- und Echokenndaten des Kanals; und

Auswahl einer Trägerfrequenz und einer Baud-Rate für das antwortende Modem, basierend auf den von ihm abgeschätzten Signal- und Echokenndaten des Kanals.

8. Das Verfahren nach Anspruch 7, bei dem das erste, zweite, dritte und vierte Zeitsegment in der Startprozedur aufeinander folgen, und bei dem das eine Modem das anrufende Modem ist und das andere Modem das antwortende Modem ist.

9. Das Verfahren nach Anspruch 7, das die folgenden Schritte enthält:

Austausch der Informationen der jeweiligen Trägerfrequenzen und der Baud-Raten zwischen dem anrufenden und dem antwortenden Modem über das Kommunikationsmedium; und

Bestimmung einer Trägerfrequenz und einer Baud-Rate für jedes des anrufenden und antwortenden Modems aus den ausgewählten und ausgetauschten Trägerfrequenzen bzw. Baud-Raten.

10. Das Verfahren nach Anspruch 7, das weiter die folgenden Schritte enthält:

Training eines Empfängers und eines Echobeseitigers für jedes des anrufenden und antwortenden Modems durch Austausch von Signalen zwischen ihnen über das Kommunikationsmedium bei der jeweils von ihnen bestimmten Trägerfrequenz und Baud-Rate; und

Austausch von Daten zwischen dem anrufenden und dem antwortenden Modem über den Kommunikationskanal bei der jeweils von ihnen bestimmten Trägerfrequenz und Baud-Rate.

Revendications

1. Modem 2 fils pour communiquer avec un modem distant sur un support de communication, le modem 2 fils ayant un émetteur pour transmettre des signaux sur le support de communication, un récepteur pour recevoir des signaux du support de communication ; un processeur de contrôle de ligne pour envoyer et recevoir des signaux de contrôle de ligne, et un suppresseur d'écho pour supprimer les échos dans le support de communication, le modem 2 fils **caractérisé en ce que** le processeur de contrôle de ligne comprend :

un moyen (34) pour transmettre pendant un premier intervalle de temps prédéterminé un premier signal de contrôle de ligne de composantes fréquentielles variables sur ledit support de communication ;

un moyen (38) pour recevoir au moins un signal d'écho dudit premier signal de contrôle de ligne dudit support de communication dans ledit premier intervalle de temps prédéterminé ;

un moyen (38) pour recevoir un second signal de contrôle de ligne de composantes fréquentielles variables dudit support de communication dans un second intervalle de temps prédéterminé ;

un moyen (80) pour estimer des caractéristiques de signal du support de communication basées sur une analyse dudit second signal de contrôle de ligne reçu ;

un moyen (50) pour estimer des caractéristiques d'écho du support de communication basées sur une analyse dudit au moins un signal d'écho reçu dudit premier signal de contrôle de ligne ; et

un moyen (84) pour sélectionner une fréquence porteuse et une vitesse de transmission d'entre une pluralité de fréquences porteuses et de vitesses de transmission basées sur lesdits estimations des caractéristiques d'écho et de signal du support de communication.

2. Modem 2 fils suivant la revendication 1 dans lequel :

le moyen d'estimation (50) inclut un moyen pour calculer un rapport signal/bruit sur un spectre de fréquences prédéterminé dudit second signal de contrôle de ligne reçu et un rapport signal-sur-écho sur le spectre de fréquences prédéterminé dudit au moins un signal d'écho reçu et, s'il est sélectionné, le moyen pour calculer inclut un calculateur de Transformée de Fourier Rapide (TFR) ; et dans lequel le moyen de sélection (84) inclut un moyen pour déterminer au moins une bande de fréquences de communication souhaitable du support de communication à l'intérieur du spectre de fréquences prédéterminé en fonction des rapports signal/bruit et signal-sur-écho calculés et pour sélectionner la fréquence porteuse et la vitesse de transmission en fonction de ladite au moins une bande de fréquences de communication souhaitable.

3. Modem 2 fils suivant la revendication 1 dans lequel les premier et second signaux de contrôle de ligne incluent un signal à impulsions modulées en fréquence s'échelonnant d'une première fréquence à une seconde fréquence qui est répété une pluralité de fois sur lesdits premier et second intervalles de temps prédéterminés respectifs ; et dans lequel le moyen d'estimation (50) inclut un moyen pour estimer une moyenne des caractéristiques de signal, basées sur une analyse du signal à impulsions modulées en fréquence répétitif du second signal de contrôle de ligne, et un moyen pour estimer une moyenne des caractéristiques d'écho, basées sur une analyse du signal à impulsions modulées en fréquence répétitif du premier signal de contrôle de ligne.

4. Modem 2 fils suivant la revendication 1 dans lequel le moyen de sélection (84) inclut un moyen pour sélectionner la fréquence porteuse et la vitesse de transmission en fonction également du au moins un débit de données désiré.

5. Modem 2 fils suivant la revendication 1 dans lequel le moyen d'estimation inclut un moyen (80) pour estimer les caractéristiques de signal, incluant une distorsion de signal non linéaire du support de communication, et un moyen pour estimer des caractéristiques d'écho, incluant des non linéarités dans au moins un trajet d'écho du premier signal de contrôle de ligne dans le support de communication.

6. Modem 2 fils suivant la revendication 4 dans lequel le moyen (84) pour sélectionner la fréquence porteuse et la vitesse de transmission inclut un moyen pour recevoir des informations de l'autre modem, lesdites informations incluant une fréquence porteuse, une vitesse de transmission et un débit de données auxquels l'autre modem prévoit de communiquer, et un moyen pour décider lesquels de la fréquence porteuse reçue et sélectionnée, de la vitesse de transmission et du débit de données seront finalement utilisés par le modem 2 fils dans la communication avec l'autre modem sur le support de communication.

7. Procédé de sélection d'une fréquence porteuse et d'une vitesse de transmission pour la communication entre un modem d'appel et un modem de réponse sur une voie d'un support de communication, la voie introduisant un retard à l'aller et au retour, également appelé plage, ente le modem d'appel et le modem de réponse, lesdites fréquence porteuse et vitesse de transmission sélectionnées pendant une procédure de mise en route commune ayant une pluralité de segments de temps successifs, le procédé étant **caractérisé par** les étapes de :

transmission (34) d'un premier signal de composantes fréquentielles variables sur ladite voie dans un segment de temps ;

réception (38) d'au moins un signal d'écho dudit premier signal de ladite voie ;

réception (38) d'un deuxième signal de compo-

santes fréquentielles variables sur ladite voie dans un deuxième segment de temps ;
estimation (122) d'une plage pour un des modems d'appel et de réponse dans ledit un segment de temps de la pluralité de segments de temps successifs de la procédure de mise en route ;
estimation (124) des caractéristiques de signal de la voie pour le un modem basées sur une analyse dudit deuxième signal reçu dans ledit deuxième segment de temps de ladite pluralité tout en estimant parallèlement des caractéristiques d'écho de la voie pour l'autre des modems d'appel et de réponse basées sur ledit au moins un signal d'écho reçu dudit premier signal ;
transmission (34) d'un troisième signal de composantes fréquentielles variables sur ladite voie dans un troisième segment de temps ;
réception (38) d'au moins un signal d'écho dudit troisième signal de ladite voie ;
réception (38) d'un quatrième signal de composantes fréquentielles variables sur ladite voie dans un quatrième segment de temps ;
estimation (182) d'une plage pour l'autre modem dans ledit troisième segment de temps de ladite pluralité; et
estimation (184) des caractéristiques de signal de la voie pour l'autre modem basées sur une analyse dudit quatrième signal reçu dans ledit quatrième segment de temps de ladite pluralité tout en estimant parallèlement des caractéristiques d'écho de la voie pour le un modem basées sur ledit au moins un signal d'écho reçu dudit troisième signal ;
sélection d'une fréquence porteuse et d'une vitesse de transmission pour le modem d'appel basée sur le signal estimé et les caractéristiques de la voie d'écho de celui-ci ; et
sélection d'une fréquence porteuse et d'une vitesse de transmission pour le modem de réponse basée sur le signal estimé et les caractéristiques de la voie d'écho de celui-ci.

8. Procédé suivant la revendication 7 dans lequel le premier, deuxième, troisième et quatrième segments de temps sont successifs dans la procédure de mise en route et dans lequel le un modem est le modem d'appel et l'autre modem est le modem de réponse.

9. Procédé suivant la revendication 7 incluant les étapes de :

échange des informations de fréquence porteuse et de vitesse de transmission respectives sur le support de communication entre les modems d'appel et de réponse ; et
détermination d'une fréquence porteuse et d'une vitesse de transmission pour chacun des modems d'appel et de réponse, respectivement, à partir des fréquences porteuses et des vitesses de transmission échangées et sélectionnées.

10. Procédé suivant la revendication 7 incluant de plus les étapes de :

conditionnement d'un récepteur et d'un suppresseur d'écho de chacun des modems d'appel et de réponse en échangeant des signaux entre eux sur le support de communication à la fréquence porteuse et à la vitesse de transmission déterminées respectives de celui-ci ; et
échange de données entre les modems d'appel et de réponse sur le support de communication à la fréquence porteuse et à la vitesse de transmission déterminées respectives de celui-ci.

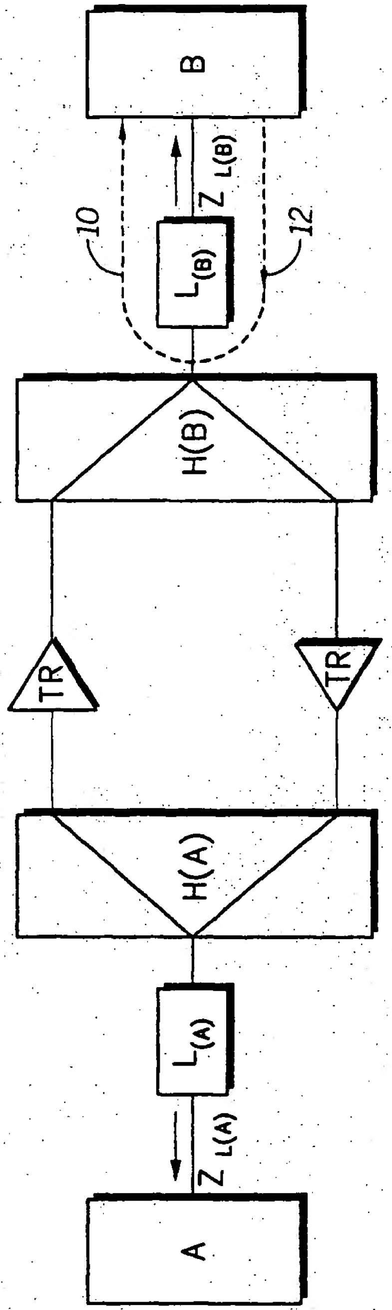
A
B
L(A)
L(B)
Z L(A)
Z L(B)
H(A)
H(B)
TR
TR
10
12

FIG.1

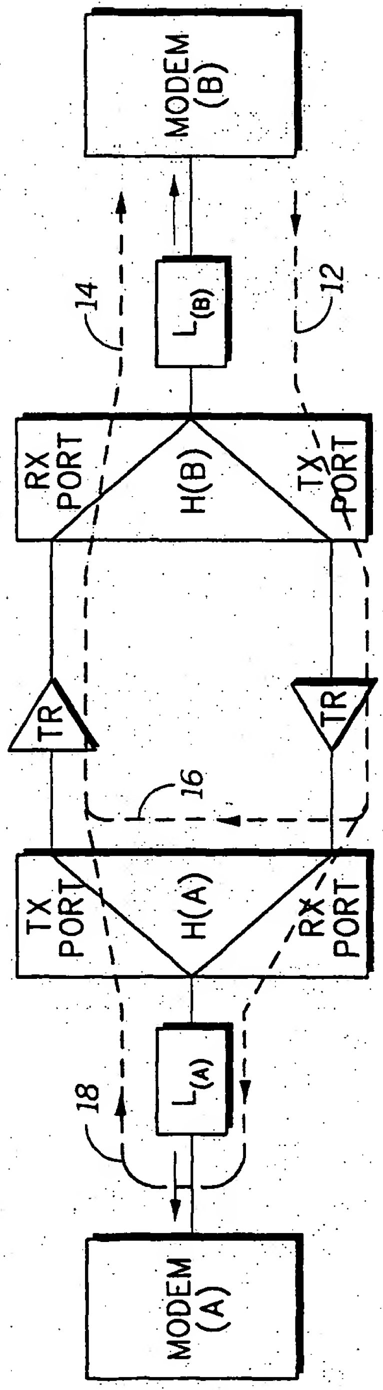
MODEM (A)
MODEM (B)
L(A)
L(B)
H(A)
H(B)
TX PORT
RX PORT
RX PORT
TX PORT
TR
TR
12
14
16
18

FIG.2

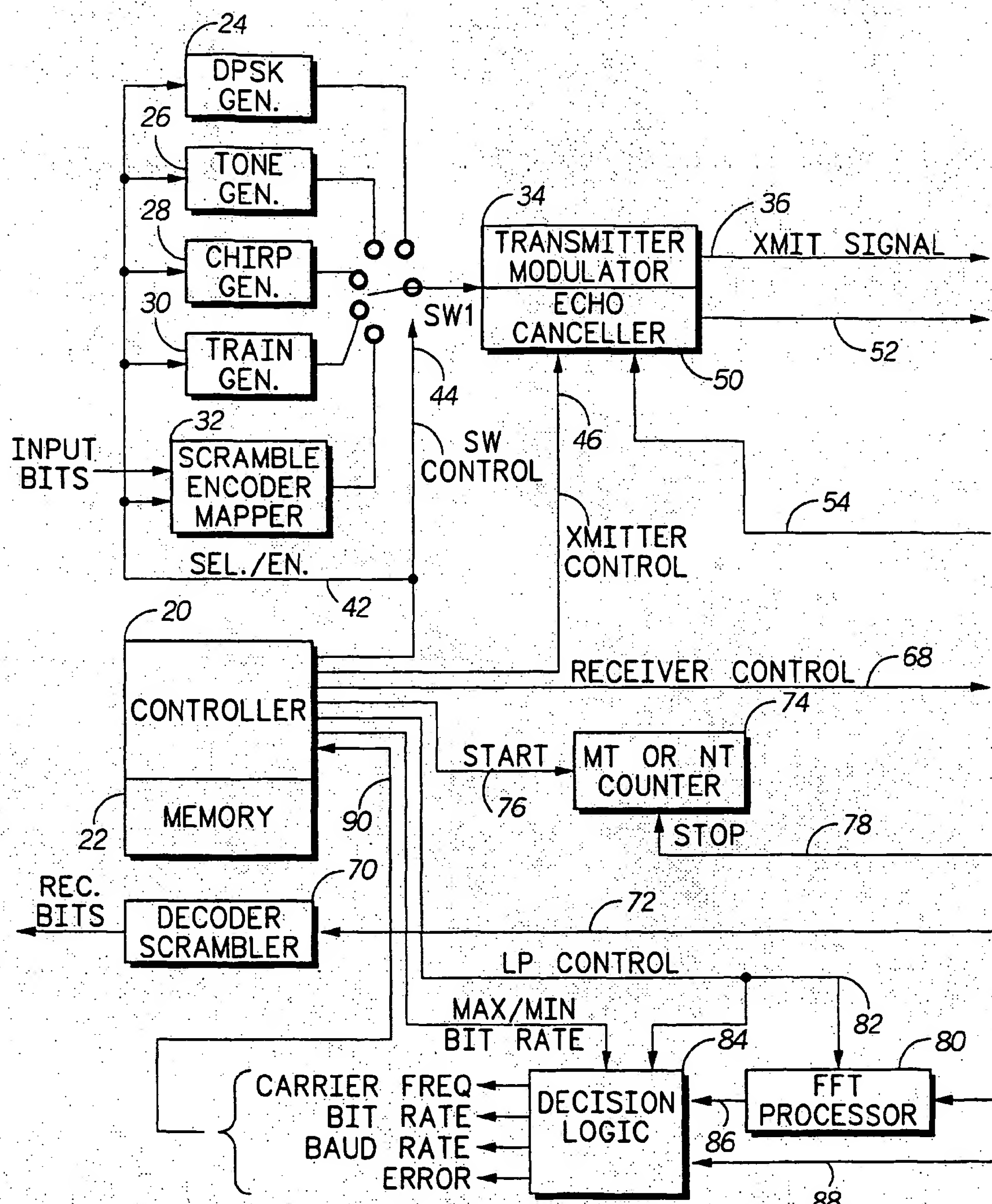
24
DPSK GEN.
26
TONE GEN.
28
CHIRP GEN.
30
TRAIN GEN.
32
SCRAMBLE ENCODER MAPPER
INPUT BITS
SEL./EN.
42
SW1
44
SW CONTROL
34
TRANSMITTER MODULATOR
ECHO CANCELLER
36
XMIT SIGNAL
52
50
46
XMITTER CONTROL
54
20
CONTROLLER
MEMORY
22
RECEIVER CONTROL
68
START
76
MT OR NT COUNTER
74
STOP
78
90
REC. BITS
DECODER SCRAMBLER
70
72
LP CONTROL
82
MAX/MIN BIT RATE
84
80
DECISION LOGIC
FFT PROCESSOR
86
88
CARRIER FREQ
BIT RATE
BAUD RATE
ERROR

FIG.3A

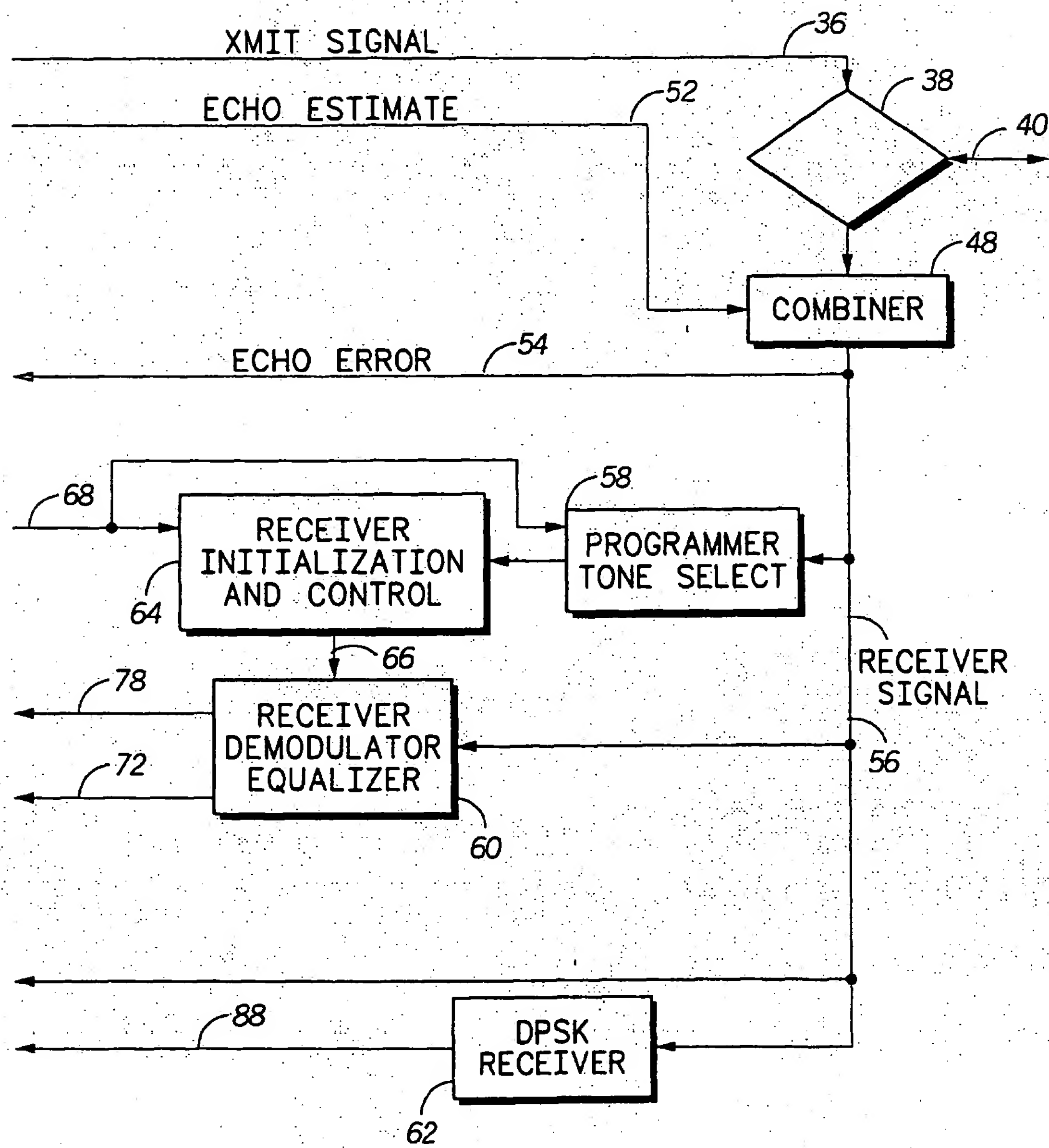
XMIT SIGNAL
36
ECHO ESTIMATE
52
38
40
48
COMBINER
ECHO ERROR
54
68
58
RECEIVER INITIALIZATION AND CONTROL
PROGRAMMER TONE SELECT
64
66
78
RECEIVER SIGNAL
RECEIVER DEMODULATOR EQUALIZER
72
56
60
88
DPSK RECEIVER
62

FIG.3B

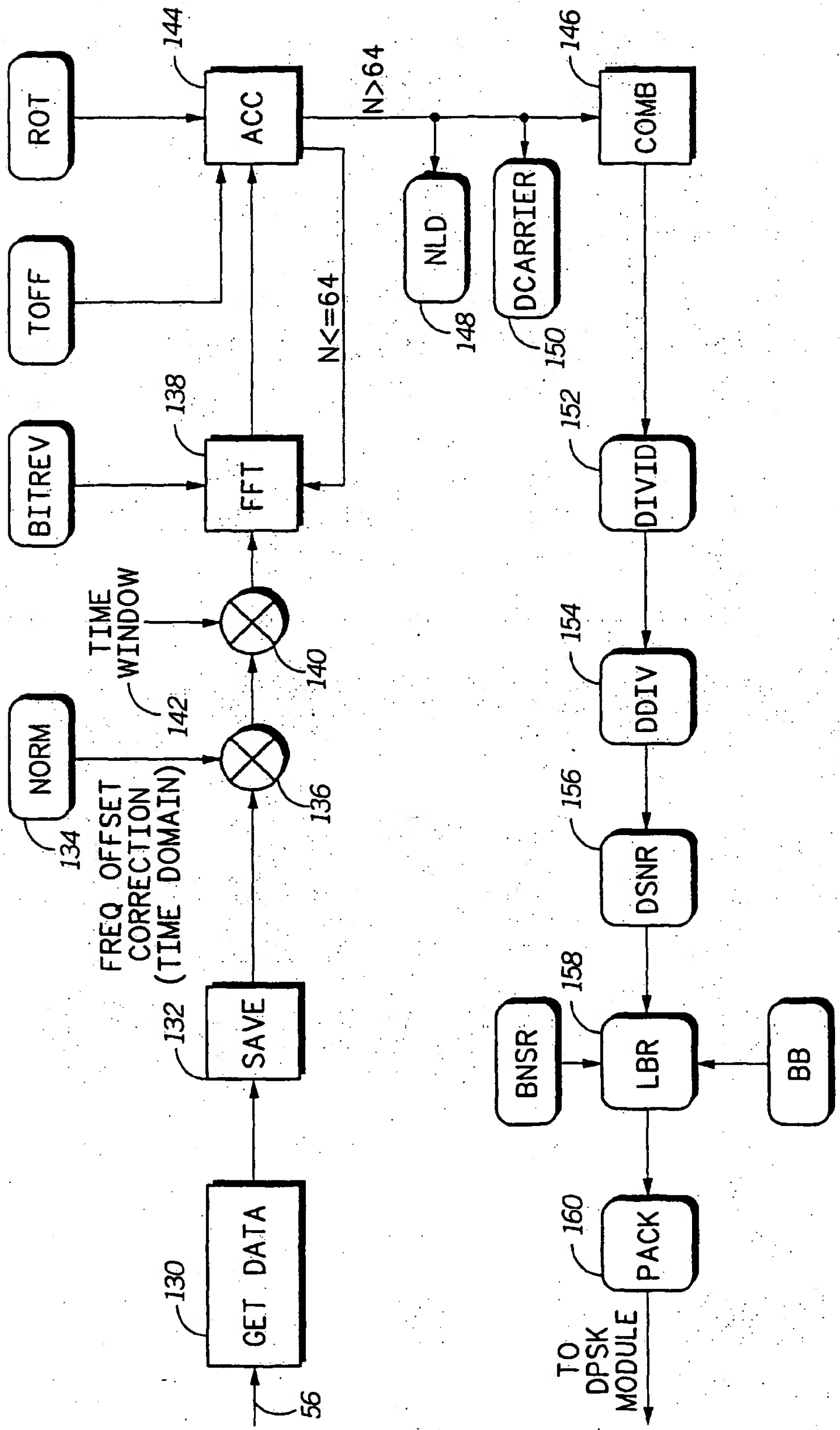
56
GET DATA
130
SAVE
132
FREQ OFFSET
CORRECTION
(TIME DOMAIN)
NORM
134
136
TIME
WINDOW
142
140
FFT
138
BITREV
TOFF
ROT
ACC
144
N<=64
N>64
NLD
148
DCARRIER
150
COMB
146
DIVID
152
DDIV
154
DSNR
156
LBR
158
BNSR
BB
PACK
160
TO
DPSK
MODULE

FIG. 4

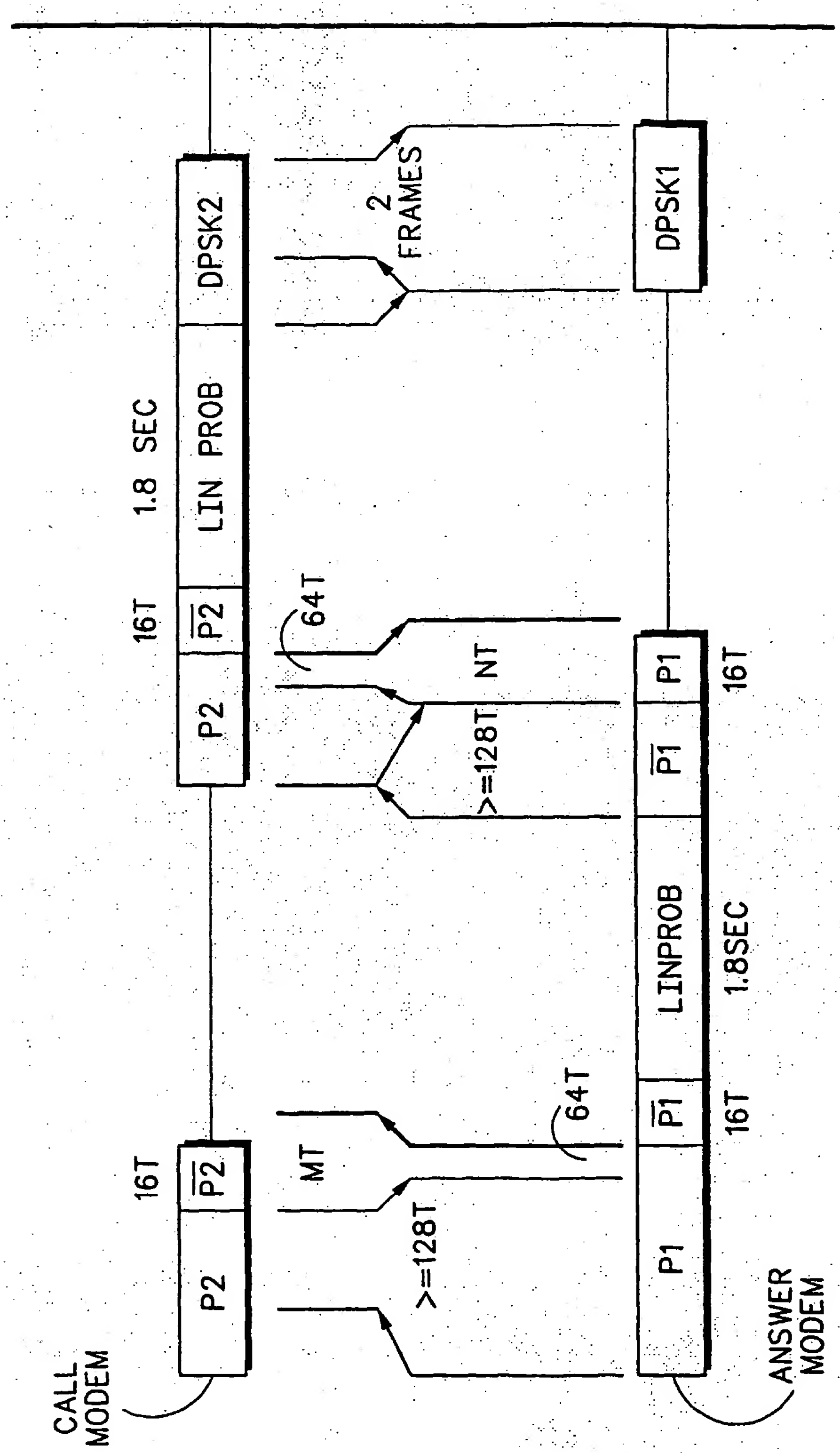
CALL MODEM
ANSWER MODEM
P2
$\overline{P2}$
16T
P2
$\overline{P2}$
16T
LIN PROB
1.8 SEC
DPSK2
DPSK1
2 FRAMES
64T
NT
>=128T
MT
64T
>=128T
P1
$\overline{P1}$
16T
LINPROB
1.8SEC
$\overline{P1}$
P1
16T

FIG.5

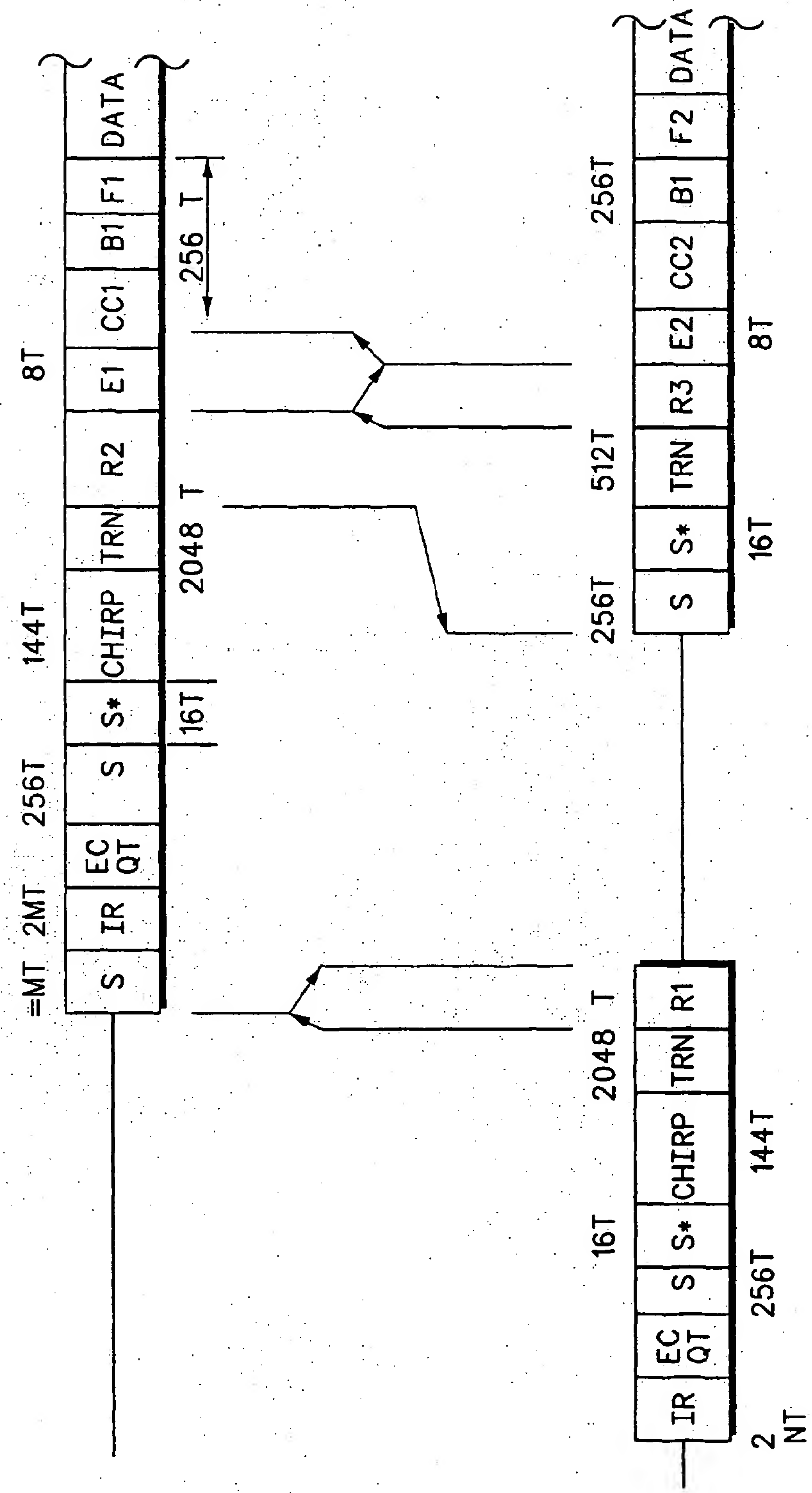
S
IR
EC QT
S
S*
CHIRP
TRN
R2
E1
CC1
B1
F1
DATA
=MT
2MT
256T
144T
8T
16T
2048 T
256 T
R1
TRN
CHIRP
S*
S
EC QT
IR
2 NT
256T
144T
16T
2048 T
S
S*
TRN
R3
E2
CC2
B1
F2
DATA
256T
512T
256T
16T
8T

FIG.6

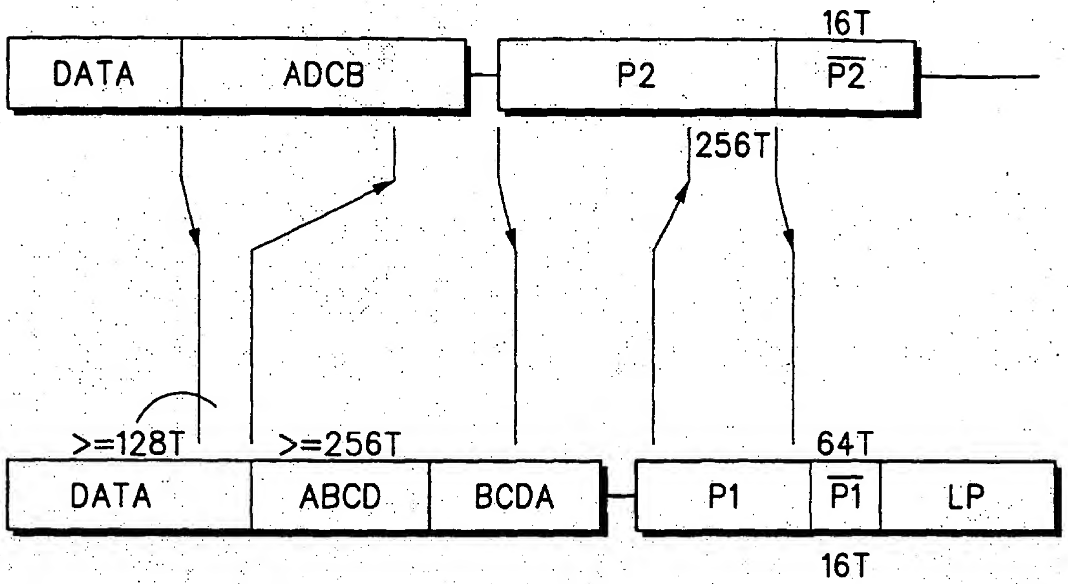
16T
DATA
ADCB
P2
$\overline{P2}$
256T
>=128T
>=256T
64T
DATA
ABCD
BCDA
P1
$\overline{P1}$
LP
16T

FIG. 7

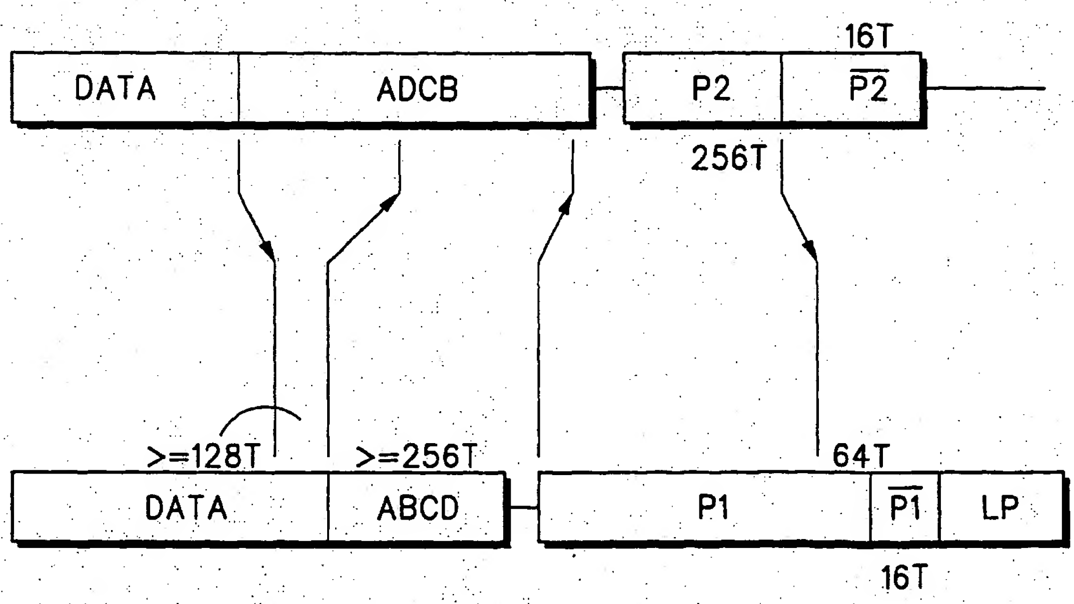
16T
DATA
ADCB
P2
$\overline{P2}$
256T
>=128T
>=256T
64T
DATA
ABCD
P1
$\overline{P1}$
LP
16T

FIG. 8

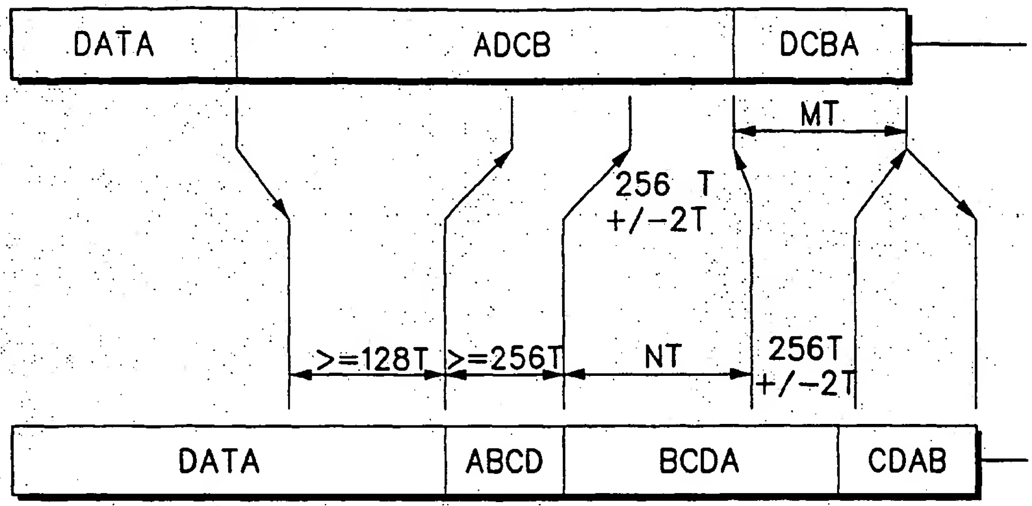
DATA
ADCB
DCBA
MT
256 T
+/-2T
>=128T
>=256T
NT
256T
+/-2T
DATA
ABCD
BCDA
CDAB

FIG.9

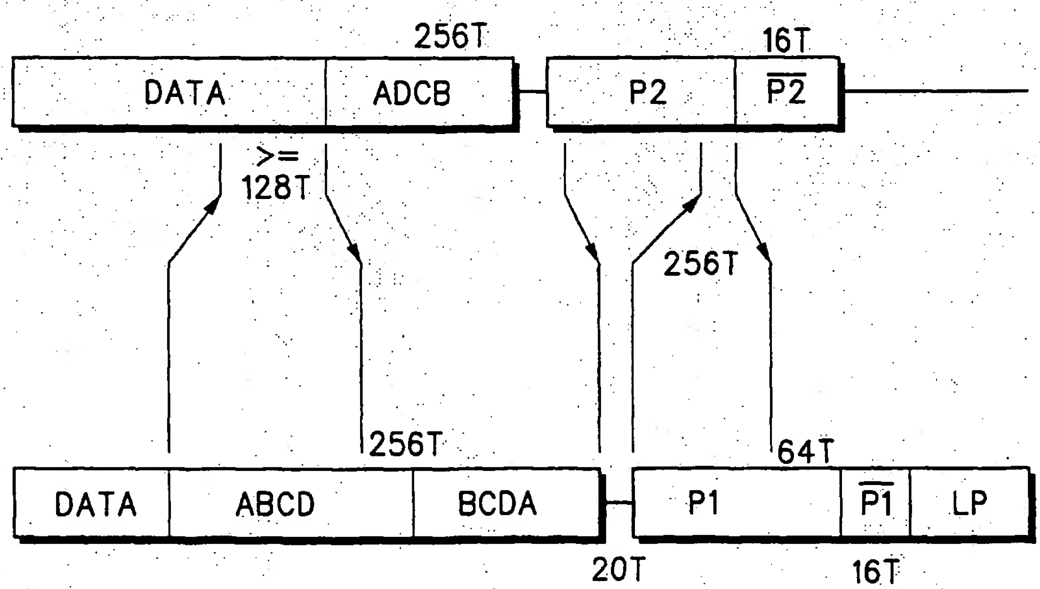
256T
16T
DATA
ADCB
P2
$\overline{P2}$
>=
128T
256T
256T
64T
DATA
ABCD
BCDA
P1
$\overline{P1}$
LP
20T
16T

FIG.10

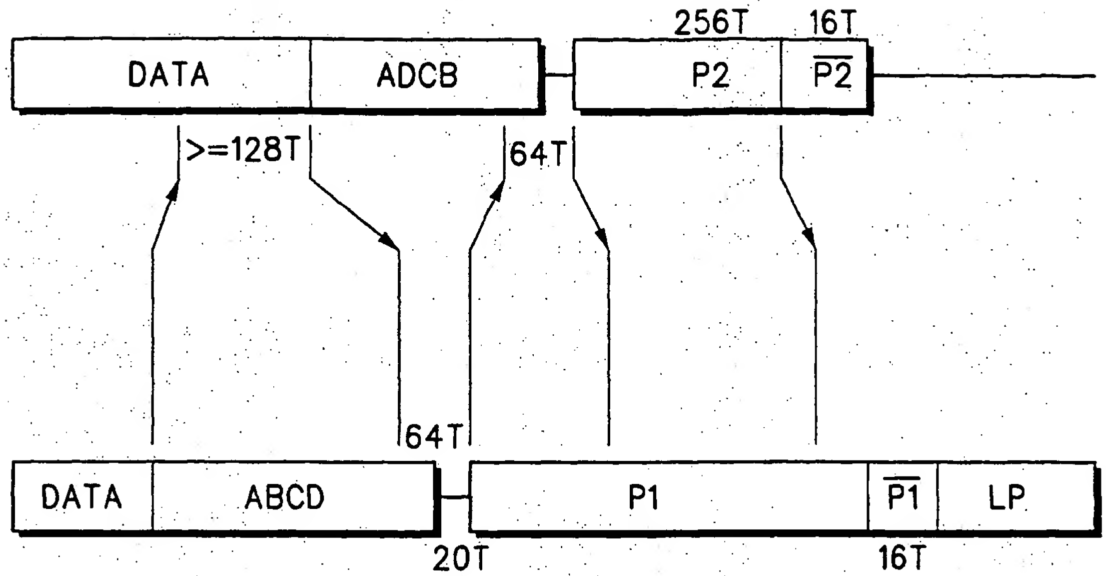
256T
16T
DATA
ADCB
P2
$\overline{P2}$
>=128T
64T
64T
DATA
ABCD
P1
$\overline{P1}$
LP
20T
16T

FIG.11

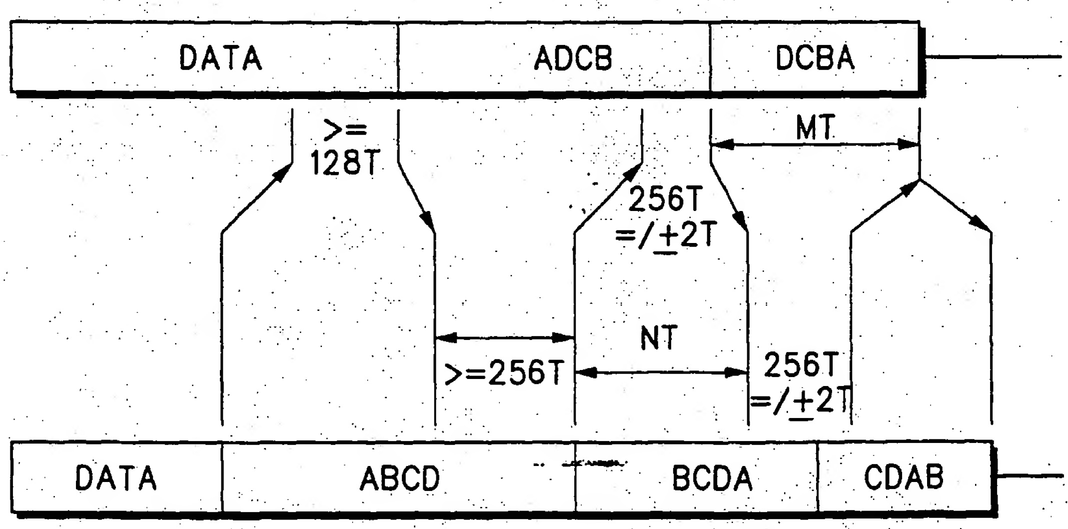
DATA
ADCB
DCBA
>= 128T
MT
256T =/±2T
NT
>=256T
256T =/±2T
DATA
ABCD
BCDA
CDAB

FIG.12

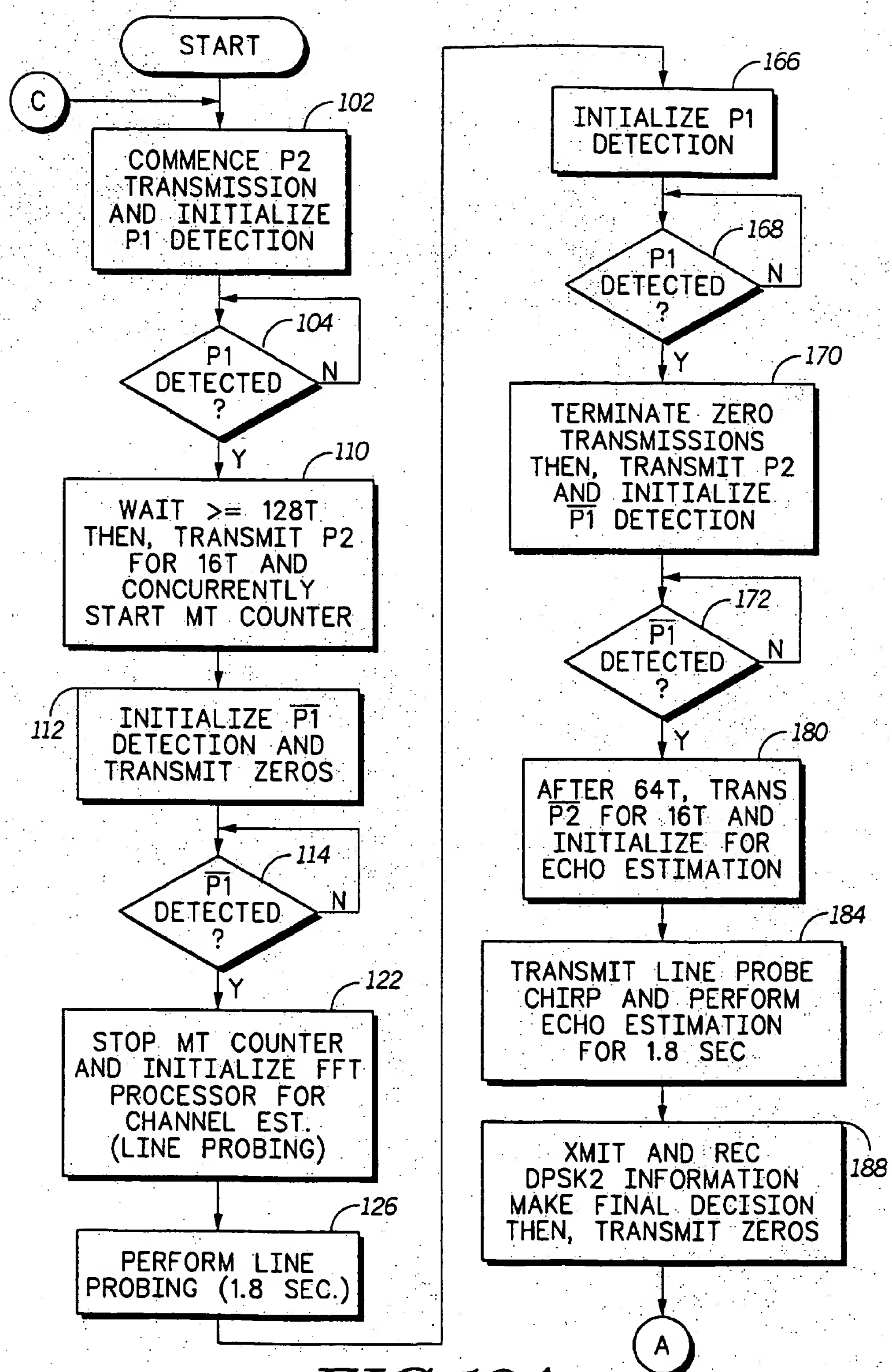
START
C
102
COMMENCE P2 TRANSMISSION AND INITIALIZE P1 DETECTION
104
P1 DETECTED ?
N
Y
110
WAIT >= 128T THEN, TRANSMIT P2 FOR 16T AND CONCURRENTLY START MT COUNTER
112
INITIALIZE $\overline{P1}$ DETECTION AND TRANSMIT ZEROS
114
$\overline{P1}$ DETECTED ?
N
Y
122
STOP MT COUNTER AND INITIALIZE FFT PROCESSOR FOR CHANNEL EST. (LINE PROBING)
126
PERFORM LINE PROBING (1.8 SEC.)
166
INTIALIZE P1 DETECTION
168
P1 DETECTED ?
N
Y
170
TERMINATE ZERO TRANSMISSIONS THEN, TRANSMIT P2 AND INITIALIZE $\overline{P1}$ DETECTION
172
$\overline{P1}$ DETECTED ?
N
Y
180
AFTER 64T, TRANS $\overline{P2}$ FOR 16T AND INITIALIZE FOR ECHO ESTIMATION
184
TRANSMIT LINE PROBE CHIRP AND PERFORM ECHO ESTIMATION FOR 1.8 SEC
188
XMIT AND REC DPSK2 INFORMATION MAKE FINAL DECISION THEN, TRANSMIT ZEROS
A

FIG.13A

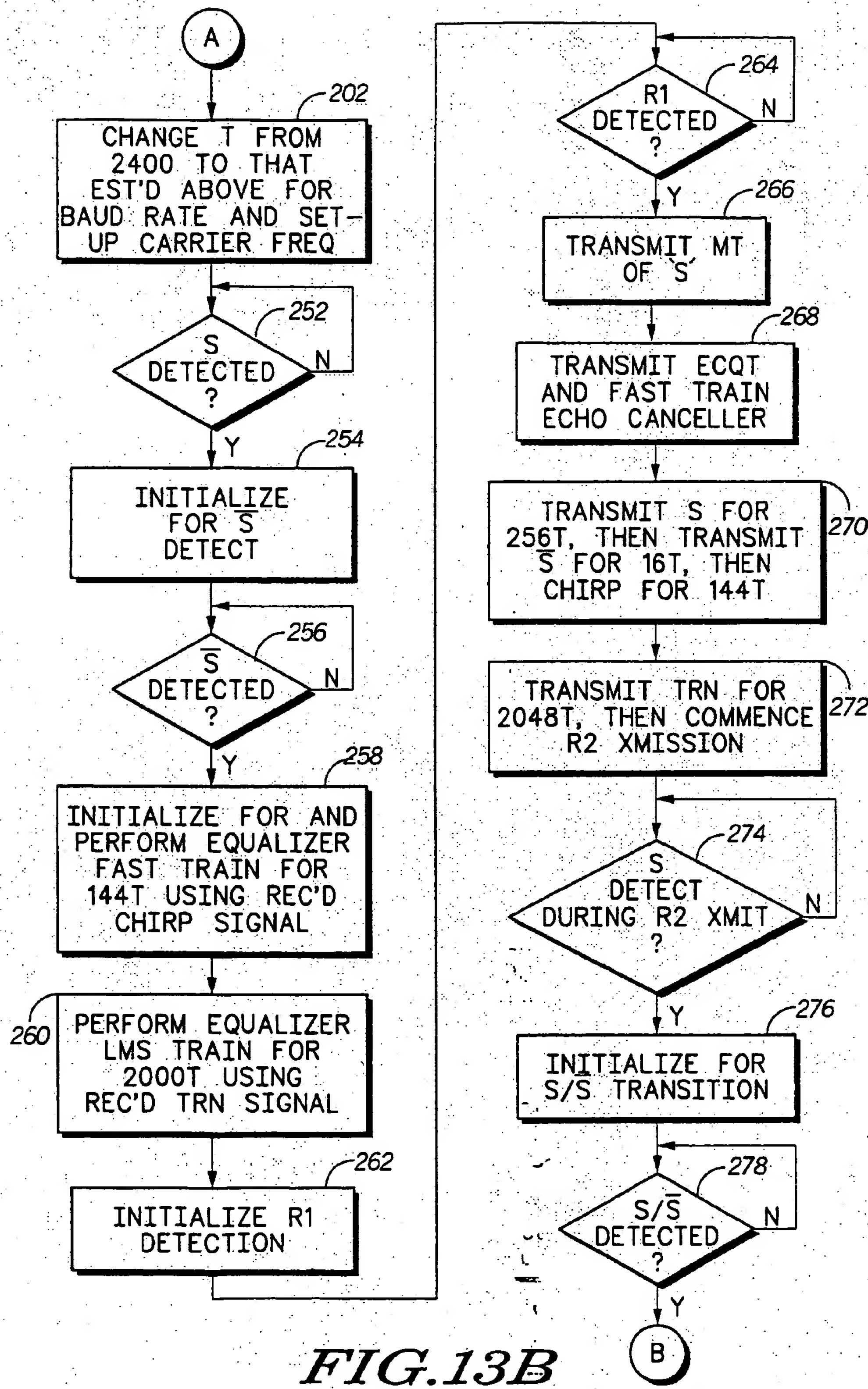
A
202
CHANGE T FROM 2400 TO THAT EST'D ABOVE FOR BAUD RATE AND SET-UP CARRIER FREQ
252
S DETECTED ?
N
Y
254
INITIALIZE FOR S̄ DETECT
256
S̄ DETECTED ?
N
Y
258
INITIALIZE FOR AND PERFORM EQUALIZER FAST TRAIN FOR 144T USING REC'D CHIRP SIGNAL
260
PERFORM EQUALIZER LMS TRAIN FOR 2000T USING REC'D TRN SIGNAL
262
INITIALIZE R1 DETECTION
264
R1 DETECTED ?
N
Y
266
TRANSMIT MT OF 'S'
268
TRANSMIT ECQT AND FAST TRAIN ECHO CANCELLER
270
TRANSMIT S FOR 256T, THEN TRANSMIT S̄ FOR 16T, THEN CHIRP FOR 144T
272
TRANSMIT TRN FOR 2048T, THEN COMMENCE R2 XMISSION
274
S DETECT DURING R2 XMIT ?
N
Y
276
INITIALIZE FOR S/S̄ TRANSITION
278
S/S̄ DETECTED ?
N
Y
B

FIG.13B

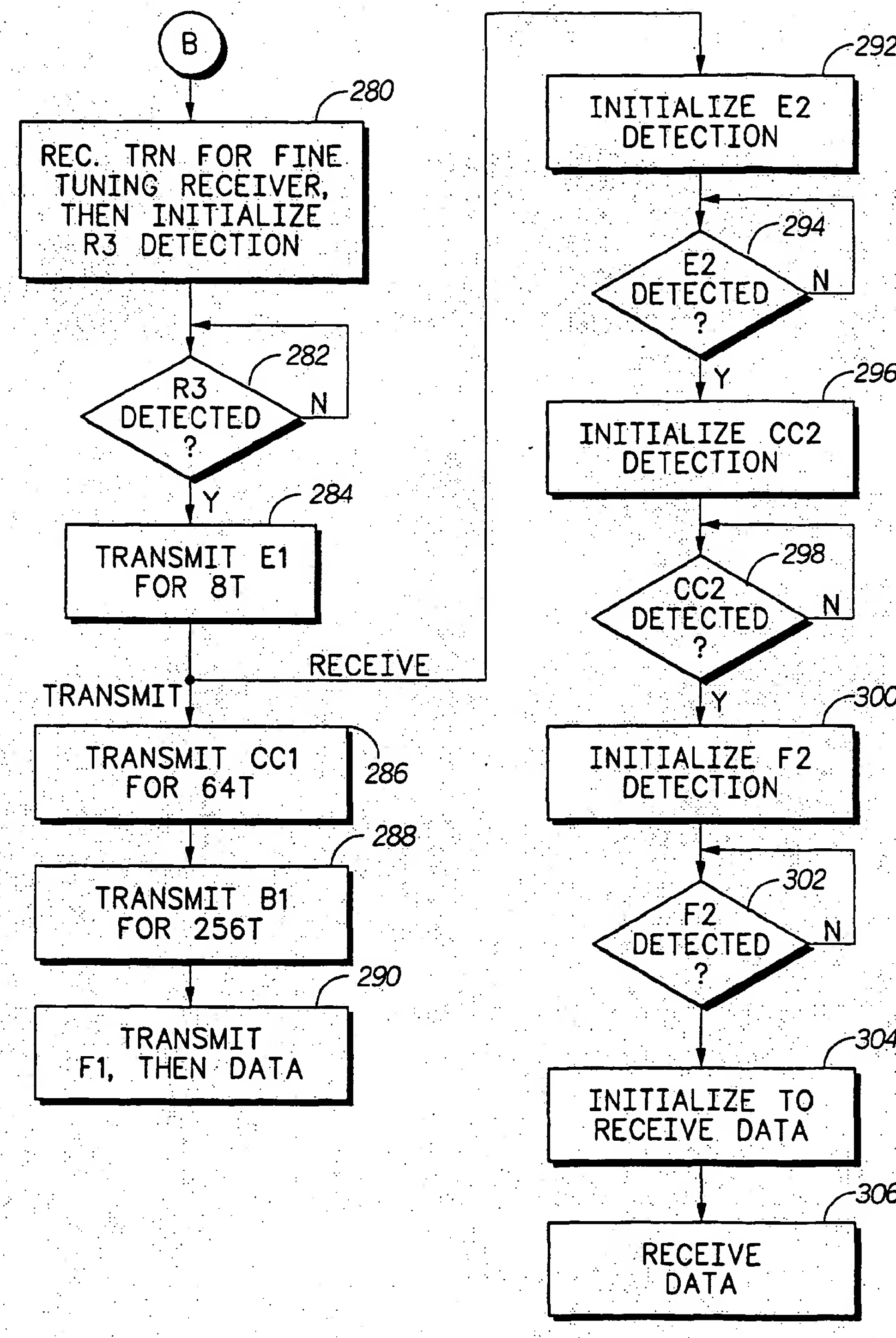
B
280
REC. TRN FOR FINE TUNING RECEIVER, THEN INITIALIZE R3 DETECTION
282
R3 DETECTED ?
N
Y
284
TRANSMIT E1 FOR 8T
RECEIVE
TRANSMIT
TRANSMIT CC1 FOR 64T
286
288
TRANSMIT B1 FOR 256T
290
TRANSMIT F1, THEN DATA
292
INITIALIZE E2 DETECTION
294
E2 DETECTED ?
N
Y
296
INITIALIZE CC2 DETECTION
298
CC2 DETECTED ?
N
Y
300
INITIALIZE F2 DETECTION
302
F2 DETECTED ?
N
304
INITIALIZE TO RECEIVE DATA
306
RECEIVE DATA

FIG.13C

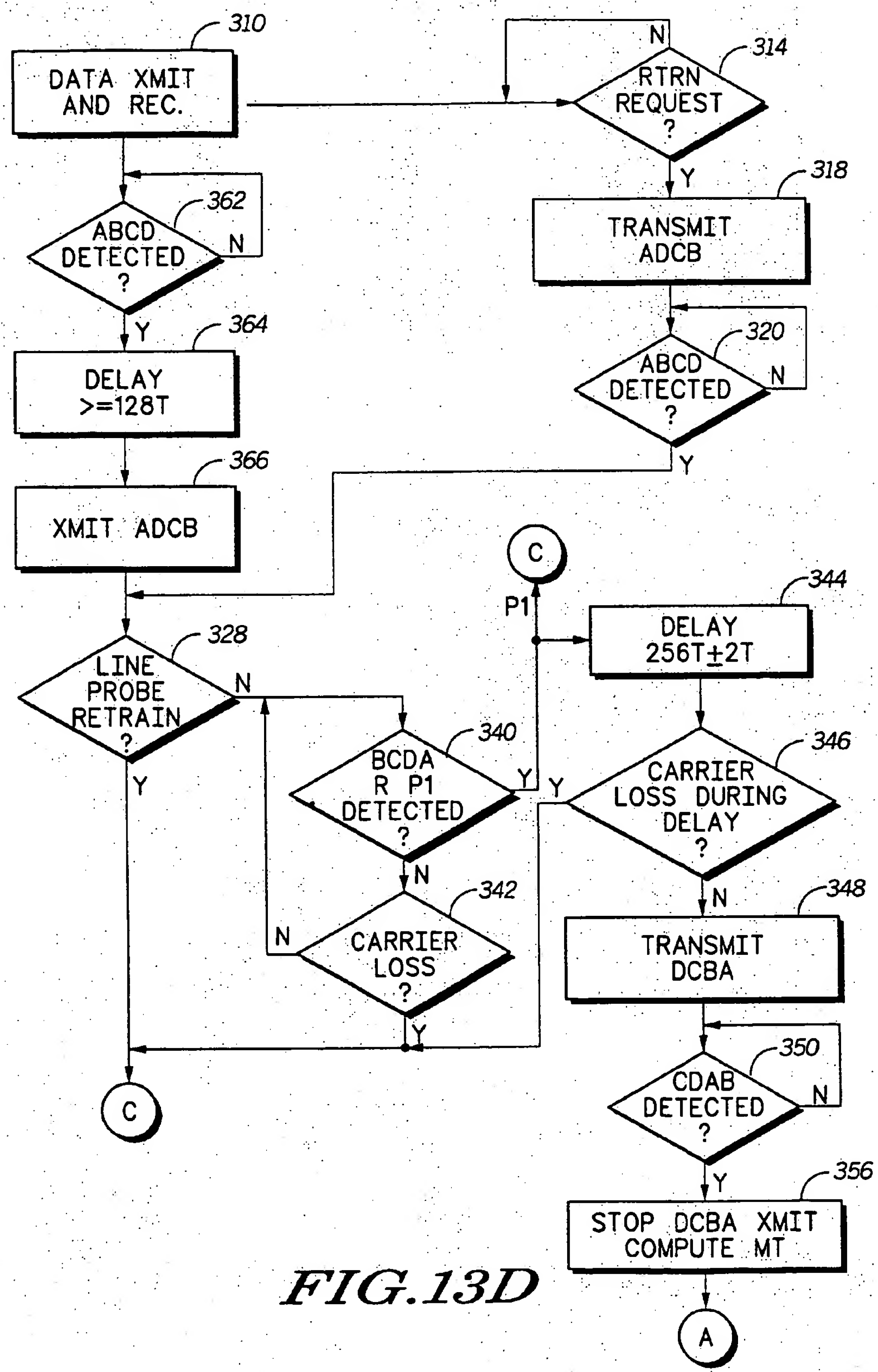
310
DATA XMIT AND REC.
314
RTRN REQUEST ?
N
Y
318
TRANSMIT ADCB
320
ABCD DETECTED ?
N
Y
362
ABCD DETECTED ?
N
Y
364
DELAY >=128T
366
XMIT ADCB
328
LINE PROBE RETRAIN ?
N
Y
340
BCDA R P1 DETECTED ?
Y
N
342
CARRIER LOSS ?
N
Y
C
P1
344
DELAY 256T±2T
346
CARRIER LOSS DURING DELAY ?
Y
N
348
TRANSMIT DCBA
350
CDAB DETECTED ?
N
Y
356
STOP DCBA XMIT COMPUTE MT
A
C

FIG.13D

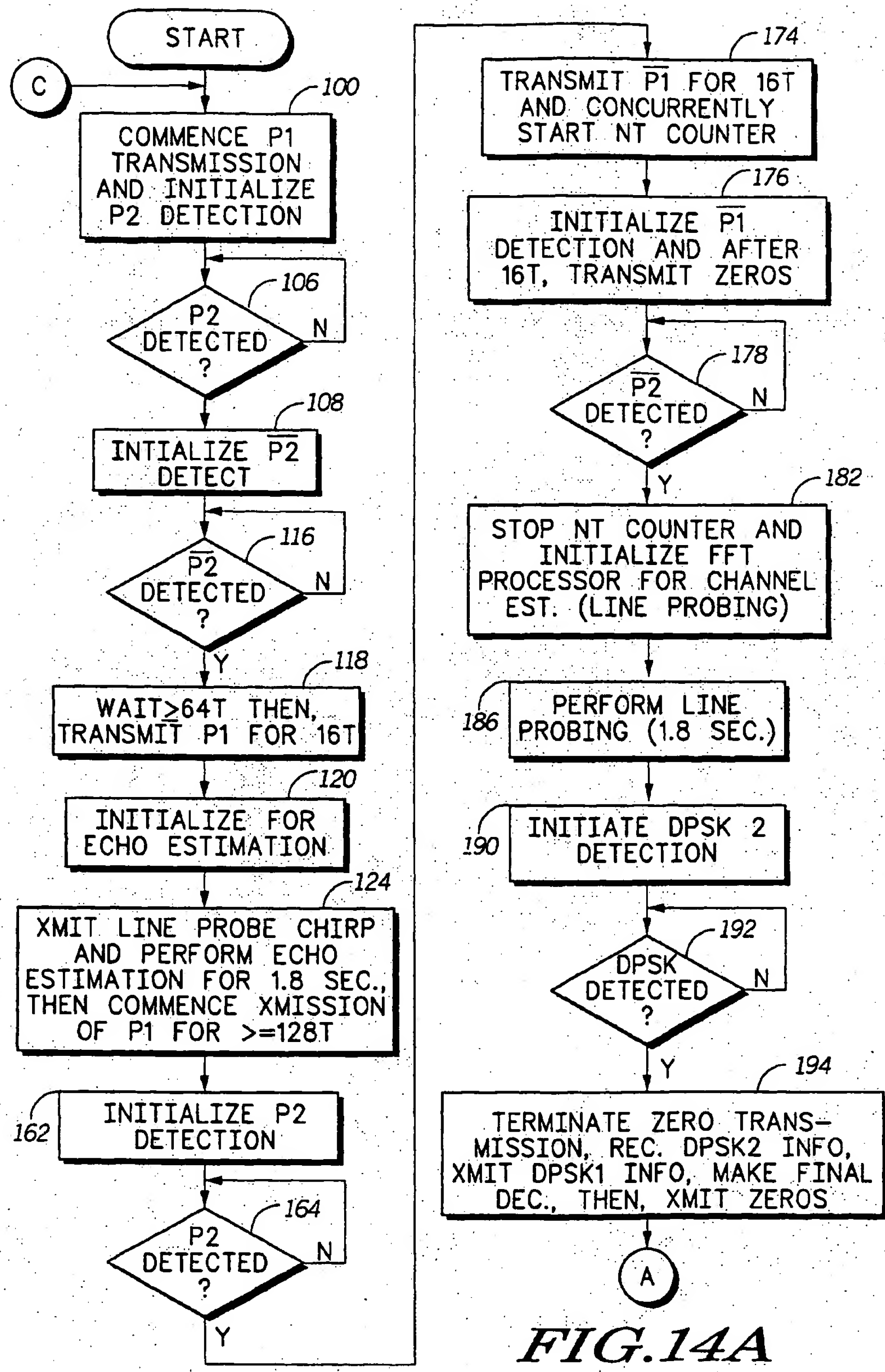
START
C
100
COMMENCE P1 TRANSMISSION AND INITIALIZE P2 DETECTION
106
P2 DETECTED ?
N
108
INTIALIZE $\overline{P2}$ DETECT
116
$\overline{P2}$ DETECTED ?
N
Y
118
WAIT≥64T THEN, TRANSMIT P1 FOR 16T
120
INITIALIZE FOR ECHO ESTIMATION
124
XMIT LINE PROBE CHIRP AND PERFORM ECHO ESTIMATION FOR 1.8 SEC., THEN COMMENCE XMISSION OF P1 FOR >=128T
162
INITIALIZE P2 DETECTION
164
P2 DETECTED ?
N
Y
174
TRANSMIT $\overline{P1}$ FOR 16T AND CONCURRENTLY START NT COUNTER
176
INITIALIZE $\overline{P1}$ DETECTION AND AFTER 16T, TRANSMIT ZEROS
178
$\overline{P2}$ DETECTED ?
N
Y
182
STOP NT COUNTER AND INITIALIZE FFT PROCESSOR FOR CHANNEL EST. (LINE PROBING)
186
PERFORM LINE PROBING (1.8 SEC.)
190
INITIATE DPSK 2 DETECTION
192
DPSK DETECTED ?
N
Y
194
TERMINATE ZERO TRANS- MISSION, REC. DPSK2 INFO, XMIT DPSK1 INFO, MAKE FINAL DEC., THEN, XMIT ZEROS
A

FIG.14A

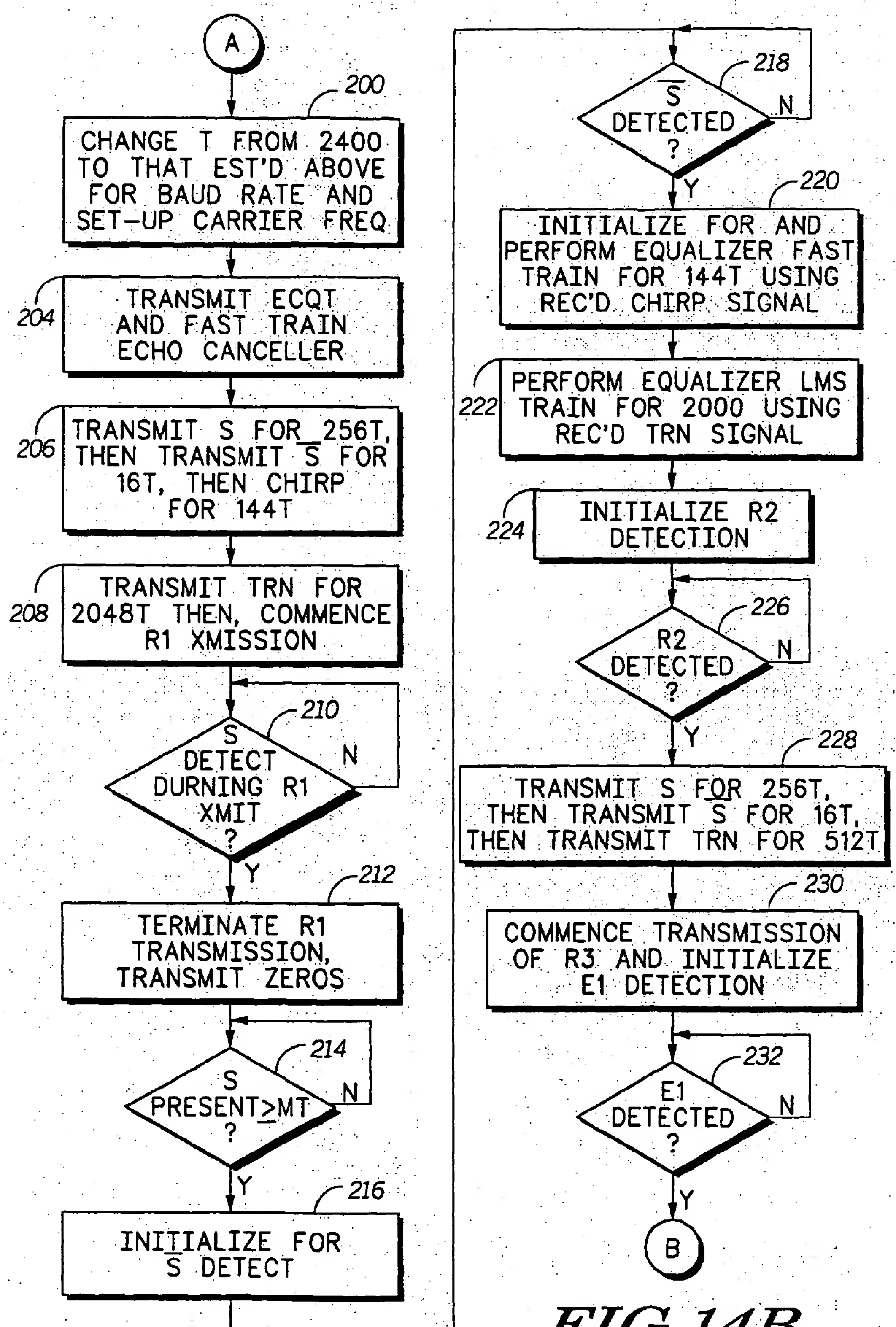
A
200
CHANGE T FROM 2400 TO THAT EST'D ABOVE FOR BAUD RATE AND SET-UP CARRIER FREQ
204
TRANSMIT ECQT AND FAST TRAIN ECHO CANCELLER
206
TRANSMIT S FOR 256T, THEN TRANSMIT S̄ FOR 16T, THEN CHIRP FOR 144T
208
TRANSMIT TRN FOR 2048T THEN, COMMENCE R1 XMISSION
210
S DETECT DURNING R1 XMIT ?
N
Y
212
TERMINATE R1 TRANSMISSION, TRANSMIT ZEROS
214
S PRESENT≥MT ?
N
Y
216
INITIALIZE FOR S̄ DETECT
218
S̄ DETECTED ?
N
Y
220
INITIALIZE FOR AND PERFORM EQUALIZER FAST TRAIN FOR 144T USING REC'D CHIRP SIGNAL
222
PERFORM EQUALIZER LMS TRAIN FOR 2000 USING REC'D TRN SIGNAL
224
INITIALIZE R2 DETECTION
226
R2 DETECTED ?
N
Y
228
TRANSMIT S FOR 256T, THEN TRANSMIT S̄ FOR 16T, THEN TRANSMIT TRN FOR 512T
230
COMMENCE TRANSMISSION OF R3 AND INITIALIZE E1 DETECTION
232
E1 DETECTED ?
N
Y
B

FIG.14B

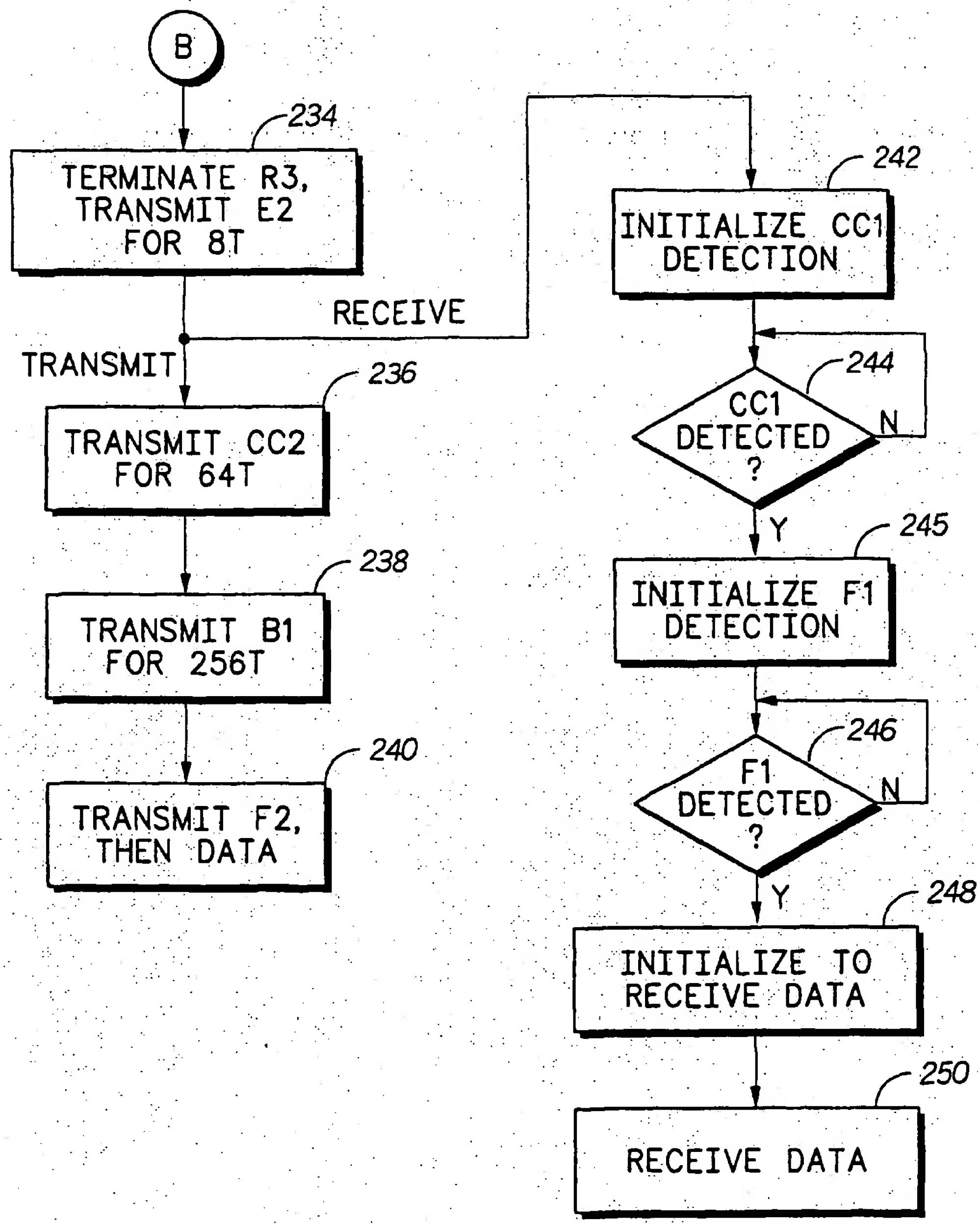
B
234
TERMINATE R3, TRANSMIT E2 FOR 8T
RECEIVE
TRANSMIT
236
TRANSMIT CC2 FOR 64T
238
TRANSMIT B1 FOR 256T
240
TRANSMIT F2, THEN DATA
242
INITIALIZE CC1 DETECTION
244
CC1 DETECTED ?
N
Y
245
INITIALIZE F1 DETECTION
246
F1 DETECTED ?
N
Y
248
INITIALIZE TO RECEIVE DATA
250
RECEIVE DATA

FIG.14C

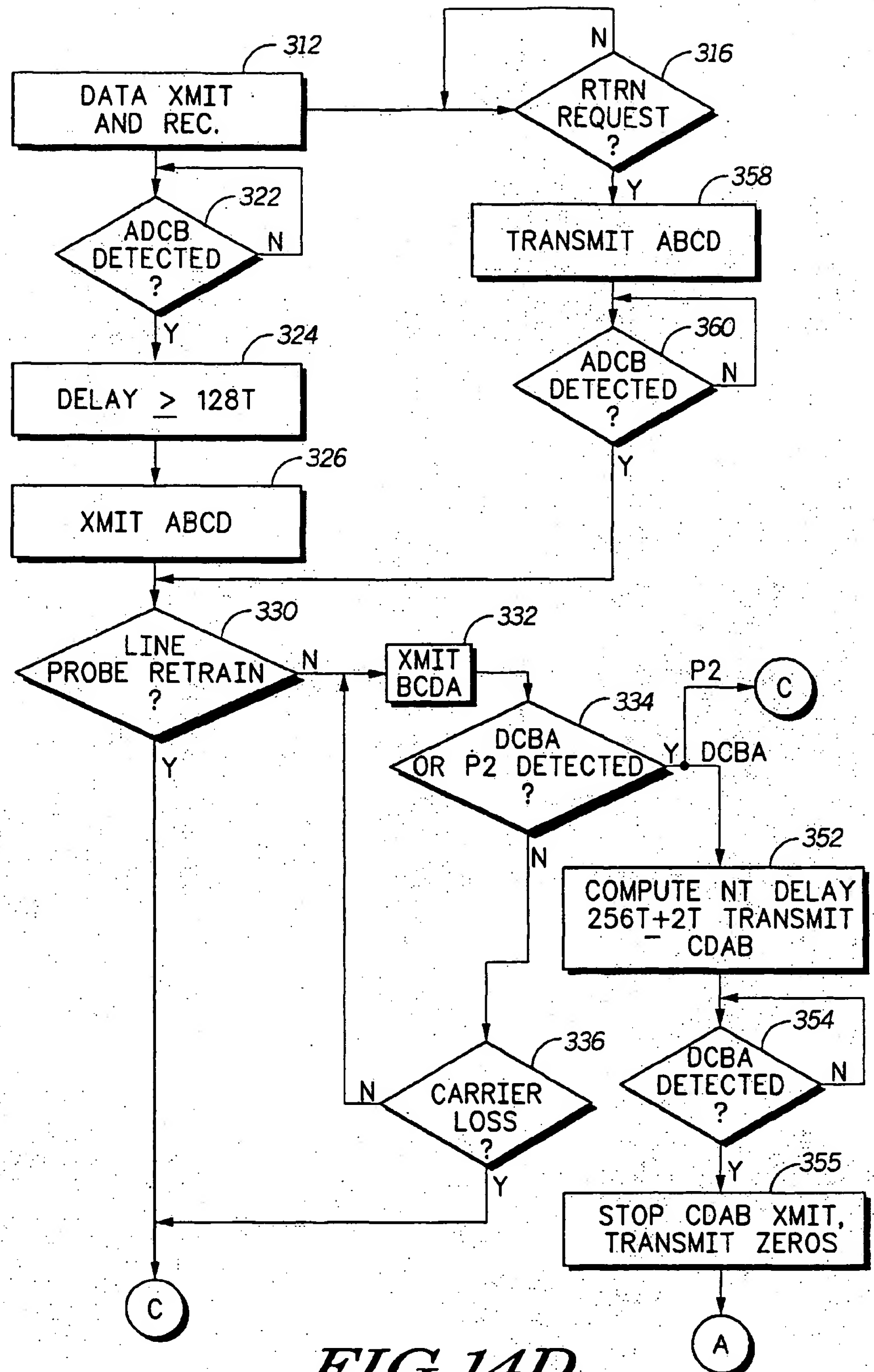
312
DATA XMIT AND REC.
316
RTRN REQUEST ?
N
Y
358
TRANSMIT ABCD
322
ADCB DETECTED ?
N
Y
324
DELAY ≥ 128T
326
XMIT ABCD
360
ADCB DETECTED ?
N
Y
330
LINE PROBE RETRAIN ?
N
Y
332
XMIT BCDA
334
DCBA OR P2 DETECTED ?
P2
C
Y
DCBA
N
352
COMPUTE NT DELAY 256T±2T TRANSMIT CDAB
336
CARRIER LOSS ?
N
Y
354
DCBA DETECTED ?
N
Y
355
STOP CDAB XMIT, TRANSMIT ZEROS
C
A

FIG.14D

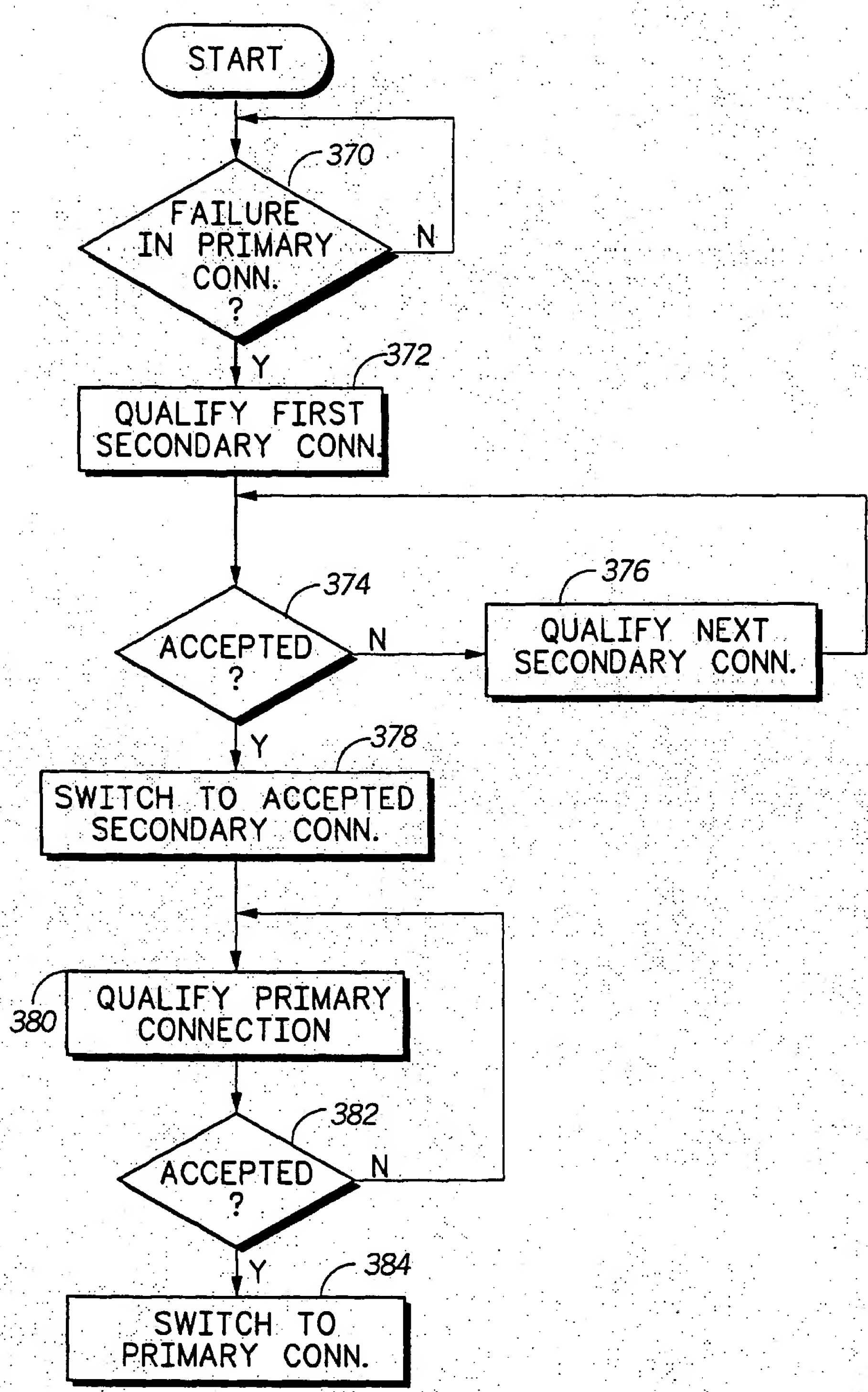
START
FAILURE IN PRIMARY CONN. ?
370
N
Y
QUALIFY FIRST SECONDARY CONN.
372
ACCEPTED ?
374
N
QUALIFY NEXT SECONDARY CONN.
376
Y
SWITCH TO ACCEPTED SECONDARY CONN.
378
QUALIFY PRIMARY CONNECTION
380
ACCEPTED ?
382
N
Y
SWITCH TO PRIMARY CONN.
384

FIG.15